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THE SLOWDOWN IN PRODUCTIVITY ADVANCES: A DYNAMIC EXPLANATION

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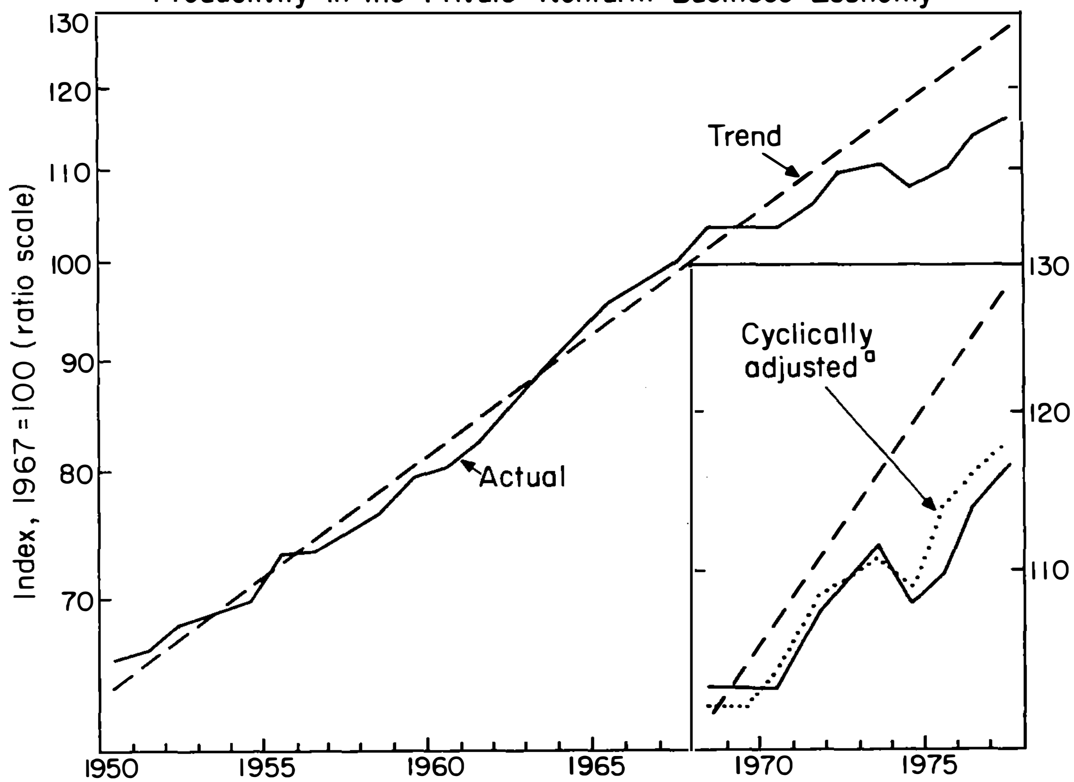
INTRODUCTION

How is the slowdown in the U.S. rate of productivity advance (see Figures I and II) to be explained? Quite obviously, before it can be explained the principal determinants of the rate of productivity advance need to be known. Many people believe that productivity advances are quite automatic, and were it not for such external factors as regulation and inflation or the declining growth rate there would be no slowdown. But without knowing what determines the rate of productivity increase how can we be sure?

Individual gains in productivity can, of course, come about in a variety of ways. For example, at any moment there are limits on the physical efficiency of machines as determined by the best available fuels and materials. One way of improving productivity consists of discovering ways to overcome these limits by either improving existing machines or discovering new ones. Another way of improving productivity consists of overcoming difficult scaling problems, as had to be overcome in scaling down turbine engines before they could be used in airplanes or in scaling up the size of coal buring electric power plants to make them more efficient. Sometimes, increases in productivity are

FIGURE I

Productivity in the Private Nonfarm Business Economy



a The cyclical adjustment is based on a regression of productivity on the current and lagged unemployment rote from 1950 to 1968. (Dept. of Labor and Council of Economic Advisers).

Source: Jimmy Corter, Economic Report of the President (U.S., G.P.O. 1978).

FIGURE II

Trends in Productivity in Manufacturing
(average annual rate of change)

Source: Gerald Ford, International Economic Report of the President (U.S., G.P.O. January 1977).

obtained by finding ways to make machines either larger or smaller. But, because of constants in materials and in the laws of nature, it is impossible to scale at will.

Almost invariably, if significant advances in technology are to result in important productivity gains they must be accompanied by organizational changes. Moreover, an organizational change can act as a triggering mechanism for advances in technology by permitting entrepreneurs to view improvements from a new perspective. For example, when the automobile industry organized its assembly lines in terms of a continuous production process rather than by type of machine, (e.g., milling or boring), entirely new possibilities, including automatic production lines, became apparent.

Although productivity advances can be triggered by either advances in technology or changes in organization, all of them involve in greater or lesser degree (depending upon the size of the particular advance) dealing with new circumstances. Therefore, the slowdown can be looked upon as a measure of the declining ability of the U.S. economy to deal with new circumstances. In the past Britain has been justly regarded as the major industrial nation with less than adequate ability to deal with new circumstances, because its long-term performance in bringing about productivity gains has been the poorest. It is apparent, therefore, that by becoming less and less able to deal with new circumstances the U.S. economy too is losing its vitality.

Alternatively, the worsening productivity performance of the United States can be described as a decline in dynamic behavior. As used in this paper the term "dynamic" is defined as the ability to deal with new circumstances by generating new alternatives. For example, by developing the Model T Ford with farmers in mind, Henry Ford was engaged in dynamic behavior because he was dealing with both a new technology and a new type of customer. One difference between static and dynamic economics is that, whereas in static economics the entrepreneur takes both tastes and alternatives as givens, in dynamic economics the entrepreneur constantly searches for loopholes in the law of supply and demand, that is, for ways to satisfy a latent demand or to satisfy an existing demand with better or less expensive alternatives. Thus we see that the productivity decline suggests a quite profound change in the American economy: a movement toward a less dynamic economy in which there is a decline in entrepreneurship.

There are, of course, economists who deny this. They believe that the productivity slowdown is a cyclical phenomenon rather than a longer-run change in the basic character of the American economy, arguing in support of this view that during the past several years the industries with the lowest growth rates are those exhibiting the poorest productivity performance. However, if my argument is correct, productivity gains represent a cause rather than a result of growth. To be sure, for productivity gains to be a cause of growth it is necessary to assume that there is price competition in the industry concerned which leads to a search for ways to reduce costs, and, furthermore, that demand

for the product in question is elastic. It is no accident that nearly all industries have shown the most growth when these conditions were fulfilled.

A key difference between static and dynamic economics is that incentives play a more significant role in dynamic economics. Dynamic economics contains not only positive incentives in the form of the quest for higher profits (the hidden hand argument invented by Adam Smith), but also negative incentives in the form of a rival dislodging a firm from a well-established market (the so-called hidden foot). Suppose that on the basis of the record of the past five years there is a 50-50 chance of a firm being dislodged from an important market. In such an industry unfortunate surprises occur so often that they hardly can be regarded as unexpected. In such an industry both the hidden hand and the hidden foot play important roles. Profits will be larger the better entrepreneurs are able to guess about promising new markets. On the other hand, in such an industry the penalties involved in ignoring one's competitors are very severe. For example, a semiconductor firm seeking to make its profits as large as possible by making only a slightly different alternative than its competitors will face almost certain bankruptcy.

An even more fundamental difference between static and dynamic economics is that, while the former is completely deterministic (with luck playing a zero role), the latter is not. Modern dynamic theory is nondeterministic not only in the sense that luck is permitted to play a significant role in outcomes, but it also acknowledges the possibility of a positive relationship between necessity and luck. The elements of necessity and luck are related because there is nothing like the hidden foot to motivate entrepreneurs to ask searching questions. To be sure, individuals differ greatly in their inquisitiveness and sense of adventure. But relatively few top executives are known for these qualities. Consequently, businesses are moved to search for new ideas only when pushed.

While Schumpeter thought of an entrepreneur as a reckless gambler who plunged knowing that his chance of success was very small, this is not my picture. The entrepreneur cannot be so defined, because with chance playing such an important role he cannot hope to know the probability of bringing about a significant advance; only if the advance is relatively trivial can he make the required calculations. The principal difference between an entrepreneur and a manager is not that the former is more reckless, but, rather, that while his relative advantage is in posing searching questions, the manager's consists of answering well-defined questions.

Why does the rate of productivity advance eventually slow down? During the Victorian period in Britain the blame was placed mainly on the conviction that the world was running out of ideas. Indeed, inasmuch as the Victorians regarded themselves as God's chosen people, there could be no other explanation. However,

an eventual decline in dynamic behavior does not indicate a drying up of economic opportunities, but, rather, it is a sign that as technologies mature the associated organizations tend to become less dynamic -- to feature managers rather than entrepreneurs. Moreover, due to an order of magnitude increase in the cost of entry, the process of establishing new firms slows down. In static economics easy entry of new firms performs the function of eliminating excess profits. But in dynamic economics new firms not only have a relative advantage in generating ideas, they have the effect of increasing the propensity to take risks in an entire industry; that is, when new firms enter an industry existing firms will consider ideas they would otherwise dismiss.

Thus, without either the entry of new firms, real challenges from other industries (for example, as the synthetic fibers industry challenged the cotton textile industry), or challenges from foreign firms (for example, as the U.S. steel industry was challenged before it sought relief), it can be predicted that the diversity of ideas generated in an industry will become narrower and narrower until finally an equilibrium is reached in which there are only trivial differences between products and rivalry is replaced by market sharing. To be sure, the engineers involved might like nothing better than to provoke genuine rivalry. However, an organization that has a minimal capability to deal with uncertainty is ill-prepared to start a conflict with its rivals. Hence a system of mutual deterrence develops, and very tight regulations are imposed on entrepreneurs lest they disturb the peace! And one of the major questions facing the nation is whether stagflation is too high a price to pay for this kind of peace.

I. THE ROLE OF TIGHT COST CONSTRAINTS IN STIMULATING ADVANCES IN PRODUCTIVITY

A tight cost constraint can be defined as one which forces an entrepreneur to develop less costly alternatives than those now available. Such constraints are adopted because of the fear of the loss of a market to a rival. Not all firms will be equally successful in keeping costs within such constraints. In fact, we can hypothesize a wide range of outcomes of R&D projects: the larger the roles that both good and bad luck play, the wider will be the variance of outcomes. However, if one rival turns out to be successful, he will have found a way to bring about a savings in either or both capital and labor inputs. In other words, he will have found a way to bring about an increase in total factor productivity.

To be sure, there are other ways to reduce costs. Costs can be reduced by cutting wages or salaries of managerial officials. However, Keynes was not the first to discover that wages are rigid in a downward direction. As early as the 1860s entrepreneurs in the British steel industry regarded improvements in productivity a better way to meet competition than reducing wages.

Now it is true, of course, that in itself a tight cost constraint cannot generate a productivity advance. A tight cost

or quality constraint is simply a way of forcing oneself to ask, "Why cannot I do a better job than has been done before?" To answer this question the firm must search for ways to bring about discontinuous reductions in costs, which is to say, it must spend money on R&D. However, while a number of studies have shown R&D expenditures and productivity gains to be highly correlated,[1] it would be wrong to conclude that the more spent on R&D, the more rapid will be the rate of productivity gain. A high correlation can be expected only as long as firms in an industry impose the same degree of cost constraint on themselves. If due to a decline in rivalry firms impose a smaller degree of constraint on themselves, their R&D expenditures may or may not increase. R&D remains a good predictor of productivity advances only as long as the degree of cost constraint and, more basically, the degree of rivalry remain constant.

Now that the relationship between productivity gains, tight cost constraints, and R&D expenditures has been clarified, it is important to introduce two concepts that play central roles in dynamic theory. The first is unambiguous feedback. The second is ambiguous feedback. Unambiguous feedback is measured in terms of changes in market shares for various catagories of close substitute products (e.g., intermediate automobiles, long-range commercial aircraft). If during the past five years, say, a 40 or 50 percent gain in market share has been typically associated with the introduction of a new product, then we can be quite sure that the hidden foot is providing other firms in the industry with a genuine incentive to take risks. Consequently it can be predicted that in such a situation searching questions will be asked and a high degree of constraint will be imposed on cost or quality. It also can be predicted that as feedback declines less searching questions will be asked and a lower degree of constraint will be imposed. In principle, of course, all firms could be equally successful in observing tight cost constraints -- with the result that market shares would remain constant. But statistically speaking, such outcomes are very unlikely.

On the other hand -- ambiguous feedback consists of all the hints and clues relevant for the generation of better alternatives. These hints can be gleaned from the firm's own activities to generate better alternatives, from those of its competitors, and by asking why particular "experiments" were not more successful. Although at times an R&D project will be unsuccessful it may contain some good ideas relevant to generating a more successful alternative. On the other hand, the entrepreneur can obtain important clues by observing the technology of another industry, from ideas contained in science, or from having observed that some ingenuous ideas embodied in an unrelated product can be relevant for an entirely different application. In short, ambiguous feedback consists of good luck with which the entrepreneur might be favored, providing, of course, that he asks the right questions.

The relationship between the two types of feedback is simply this: the higher the degree of unambiguous feedback, the tighter will be the cost constraints, the greater will be the incentive to ask searching questions, and the greater will be the role played by luck.

To illustrate these concepts and to further develop the argument several examples are herewith provided.[2]

<u>The Model T Ford</u>: The Model T Ford represented the fulfillment of Henry Ford's dream: a practical car for farmers. Having been brought up on a farm it is not surprising that he believed that farmers constituted an important segment of the market for new automobiles. Other car manufacturers tailored their products for city dwellers. For the latter market two distinctly different kinds of cars were developed: inexpensive but not durable runabouts ranging in price from $495 for a Sears & Roebuck runabout, to $650 for an Oldsmobile, to $750 for a Century Steam Car, to durable but more expensive automobiles ranging in price from $1,000 to well over $5,000. In 1908 Buick, which produced a medium-priced car for $1,000, was the top automobile producer of the nation, enjoying 25 percent of the market as compared with 10 percent for Ford.

However, neither type of car was suitable for use by farmers. The inexpensive runabouts were not rugged enough; and the more rugged cars were too expensive. Therefore the constraint imposed upon the Model T involved a more rugged automobile at more or less the same price as the inexpensive runabouts; and it helped make possible two important discoveries. The first consisted of Henry Ford's observation of a French racing car constructed of vanadium steel that would permit the manufacture of a relatively lightweight rugged automobile. Other automobile manufacturers had observed the same racing car, but apparently Ford's constraint made this discovery seem more relevant; the Model T was the first to use this type of construction.

Though the first Model Ts were stronger than other low-priced cars, they were not inexpensive. When introduced, the Model T cost $850, and in 1909, when the price went up to $950, Ford's share of the market began to decline. Thereupon a figure of $600 was adopted as his goal. To implement this goal a search for ideas to rationalize and speed up production was initiated on a wide scale. One idea which emerged from the search, that of moving production lines, is generally credited to Clarence W. Avery who had seen the concept employed in a meat packing plant. He rationalized that if moving production lines can be used to disassemble carcasses, why not for assembling automobiles!

Was it not a matter of luck that Avery happened to visit a meat packing plant? Of course it was. Luck plays an important role in all discoveries. On the other hand, were it not for the necessity of meeting tight cost and durability constraints there is not one chance in a hundred that the relevance of the process used in meat packing would have been appreciated.

Thus Ford Motor Company created a loophole in the law of supply and demand. I say "loophole" for two reasons. In the first

place, if it is assumed that the demand of farmers for such an automobile were known, then it is difficult to explain why several automobile makers did not simultaneously develop a similar car. On the other hand, Henry Ford obviously did not repeal the law of supply of demand, because after the Model T was developed the Ford Motor Company faced a downward sloping demand curve. The assumption that entrepreneurs can create loopholes in demand and/or supply conditions does not, of course, imply any disrespect for the classical law of supply and demand. On the contrary, the assumption of loopholes is needed to protect it.

While no one can say to what extent Henry Ford accepted the risk of developing a new kind of automobile because of fear of his rivals, it is nonetheless true that as of 1908 at least six automobile manufacturers which had enjoyed more than 10 percent of the market had already gone out of business. So in this kind of environment there was a big risk involved in making an automobile only marginally different from that of a competitor; in short, it was an environment in which it paid to be different.

One of the big debates in economics is to what extent a large market was responsible for the rapid economic development of the United States. There can be no question that a large market provides a country with an important potential advantage. But with a hidden hand alone, there is no assurance whatsoever that this potential will be rapidly exploited. On the contrary, if firms had taken their demand conditions as a given the automobile never would have been developed. Nevertheless, a large and diverse market provides one important advantage. It helps to insure that entrepreneurs will come from different backgrounds, and they will, therefore, think differently about demand conditions. In other words, the advantage is a statistical advantage. In European countries the probability was smaller that an automobile entrepreneur would come from a farm, and would, therefore, think like a farmer.

The DC-2 and DC-3 Commercial Airplanes: During the 1930s, more than one-half of total airline company costs were represented by airliner operating costs (including depreciation). And shortly after the Air Mail Act of 1934, which drastically curtailed subsidies to the airlines, the airline companies took the initiative by pressing for more economical airliners. In particular, Trans-World Airlines asked several firms, including Douglas, to enter a design competition for an airplane whose performance would be equivalent to that of the recently developed Boeing 247 -- but whose costs would be significantly lower. Although a two-engine airplane was generally regarded as a simpler and more economical concept than the trimotor airplanes developed during the late 1920s, because of FAA safety regulations the plane was required to fly on a single engine. Neither of Douglas' competitors at that time (Sikorsky and General Aviation) were willing to risk development of a two-engine design. That a risk was involved is indicated by the fact that the DC-2 turned out to

be 30 percent overweight and could not have met its performance requirement had it not been for the ability of the people in charge to quickly reorient the program to take advantage of the recently developed variable-pitch propeller and a more powerful engine. Thus, luck also played an important role here. However, later we shall see that conducting R&D programs to take advantage of good luck, and to minimize the consequences of bad luck, constitutes the essence of dynamic efficiency.

Now it is true, of course, that as of the time there was no airplane in direct competition with the DC-2 (only somewhat later did Lockheed develop a close competitor). However, prior to the time of the DC-1 and the DC-2 (the production version of the DC-1), Douglas had never developed a commercial airplane. So, as far as the commercial market was concerned Douglas was a newcomer. If the Douglas Company were to become an important factor in the commercial business it obviously had an incentive to take risks. (Trying to get into the commercial market by merely developing another version of the trimotor airplane would have undoubtedly involved even greater risk.) In his Wilbur Wright Memorial Lecture, Arthur Raymond who not only was on the team that developed the DC-1 and the DC-2, but later was in charge of the DC-3 program, indicated that a new entrant to a market has a somewhat different point of view from that of a well-established firm:

> What is my competitor doing? Is he so entrenched that it will be extremely difficult, if not impossible, to make

headway against him? On the other hand, has he been established in the field so long that he is perhaps growing complacent? Should he have brought out a new model some time ago and failed to do so, thus giving me an opening?[3]

Although the DC-2 resulted in a 25 percent reduction in operating costs (measured in real terms) below those achieved with the trimotor airplanes, and Lockheed's L-10 (similar in design to the DC-2) resulted in an additional savings in operating costs, this was not enough. Even with more economical airliners the major airlines were still operating at a loss. The next step was also taken by airline companies when William Littlewood, Chief Engineer for American Airlines, proposed that larger engines be utilized to develop an airplane that could carry twenty-four instead of fourteen passengers. As a consequence, the DC-3 was developed as a stretched version of the DC-2; and it resulted in bringing down seat-mile operating costs from 6.8 to 3.3 cents -- or by 50 percent.

In one important respect the development of commercial aircraft differed from that of automobiles. Its development was supported by research directly undertaken by the government (in the National Advisory Committee for Aeronautics (NACA) laboratories) and that sponsored by the universities. For example, Arthur L. Klein, of the California Institute of Technology, directly contributed to the development of the DC-2 by discovering a way to reduce drag that was previously unknown to designers of low-wing monoplanes. However, both the NACA and university laboratories

were highly responsive to the need to reduce costs.

Development of the Prototype for the Boeing 707: Boeing's experience in developing the B-47 bomber certainly gave it an advantage when it came to developing commercial jets. Yet, bombers and commercial airplanes are developed with entirely different cost constraints; that is, in the case of military airplanes the primary constraint is the performance requirement, and cost is a secondary consideration. Boeing learned this the hard way when it developed the Stratocruiser airplane as a modification of the B-29 bomber; and, although it might have been successful if delivered to the airlines before the DC-6, it was not. Consequently, relatively high operating costs, as compared with the DC-6, represented the main reason why, when unable to sell enough airplanes to recoup its initial investment, Boeing lost about fifty million dollars.

As a result, Boeing officials were determined to go about the development of a commercial jet in a manner that would not result in a repetition of the Stratocruiser experience. The principal question about the economics of the airplane arose from the fact that CAA certification requirements for commercial jet aircraft were not yet established. Moreover, the airplane's stalling speed directly affected its economics. The higher the stalling speed, the lower would be the certifiable weight, and the poorer would be the economic characteristics of the airplane inasmuch as the payload would be smaller and longer runways would be required. Further, relatively small errors in estimating the stalling speed could result in relatively large errors in estimating costs. Therefore, an experimental airplane was required to provide more accurate measurements.

A cost constraint was adopted which required a commercial jet to have no larger operating costs than piston-engine commercial aircraft. With company funds Boeing undertook the development of an experimental airplane that would serve as a prototype for both a commercial jet and an Air Force tanker. As it turned out, the 707 had lower operating costs than either the DC-7 or the Lockheed-developed turboprop airliner. However, relatively few people in the industry anticipated that the jet would have this advantage.

The Batch Process for Producing Transistors: Originally, transistors were regarded as substitutes for vacuum tubes. Although a half-dozen large receiving tube companies went into the transistor business, by the late 1950s Texas Instruments occupied the same position in the semiconductor industry as did Buick when challenged by Ford.

The story of the challenge to Texas Instrument's market leadership began in Shockley Laboratories which was established as a wholly owned subsidiary of Beckman Instruments in the mid 1950s. (Along with John Bardeen and Walter Brattain, William Shockley received the Nobel Prize for the discovery of the transistor.) Shockley Laboratories was staffed mainly by a

group of young scientists and engineers recruited from universities. However, shortly after the company was founded a serious disagreement arose between Shockley and his staff. According to reliable sources, the disagreement arose not over whether the transistor would have uses other than as a replacement for the vacuum tube, but, rather, how visionary it paid to be given the current status of the technology. While Shockley was thinking in terms of ideas which might pay off ten or twenty years later, eight of the people he had hired believed that they had an idea which would pay off in about six months.

As is the case with many important discoveries, the dissidents' concept was relatively simple. The manner by which transistors were being produced, they reasoned, was analogous to producing postage stamps one at a time. Why not produce sheets of, say, 10,000 stamps -- and later cut the sheets into individual stamps? Their motivation, however, was not so much to reduce the cost as it was to increase the performance of transistors at the same cost. They reasoned that if transistors with an order of magnitude improvement in performance could be produced at no more than what transistors currently cost, there would be additional markets for semiconductors -- most immediately in the computer industry.

Not able to persuade Shockley, the young entrepreneurs managed to convince Fairchild Camera and Instrument to finance the development of the Planar process for eighteen months. Fairchild in return received an option to buy the firm, which it later exercised.

This, however, is not the end of the story. If many transistors can be produced in one operation, why disassemble them to create complete circuits? Why not make many transistors and a complete circuit in one operation? This thinking eventually led to the drastic decline in the price of integrated circuits (more than 90 percent between 1963 and 1968) in which Fairchild played a primary role.

However, it is no accident that the evolution of semiconductors took this particular form. Had entrepreneurs continued to think in terms of producing semiconductors one at a time the idea of producing an inexpensive integrated circuit probably would not have occurred to them. So a tight quality and cost constraint not only led to one cost reducing discovery (the Planar transistor which made batch production possible), it also helped speed up the entire evolution of the technology. The same process has occurred in many other industries.

The development of transistors was but another case similar to that of the Model T Ford. By assuming that the quality elasticity of demand would be high, the people who developed the batch were able to discover a loophole in the law of supply and demand. (If the market potential and the means of achieving it were well known, why did not many firms do likewise?) Again it was fortunate that not all people in the industry had the same probability estimates with respect to demand conditions, for if all firms had acted upon the assumption that the semiconductor

was merely a replacement for vacuum tubes the real potentialities of the technology would never have become known.

Movements Away from the Center of a Distribution: The above examples provide good illustrations of dynamic processes: processes that result in steady reductions in cost, steady improvements in quality, or both. The two principal characteristics of such processes are these. In the first place, the alternatives are not becoming more and more alike -- there is no movement toward the center of a distribution. On the contrary, highly discontinuous changes can be observed that change the shape of the distribution. Secondly, they are irreversible changes -- irreversible because they change history. After the development of the Model T the world no longer looked the same either to automobile makers or to farmers; their subjective probability distributions had changed.

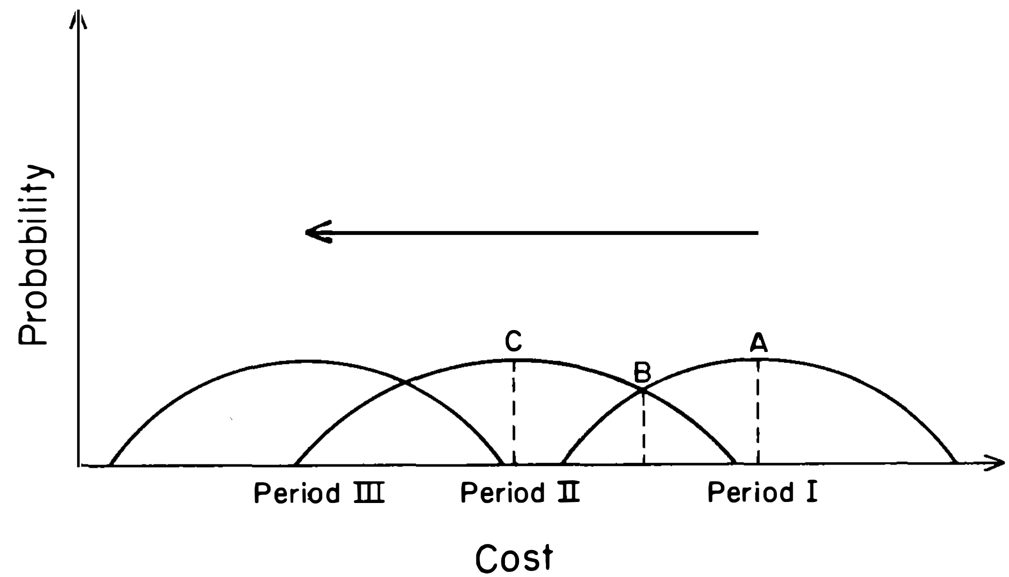
This is not to say, of course, that the alternatives always changed in the way predicted by dynamic theory. In fact, in a famous article written in 1929, Harold Hotelling lamented about a world in which he observed not only trivial differences between products, but also trivial differences between political parties.[4] On the basis of his observations he developed a model to explain such convergence toward the center of a distribution: a model that has had a profound effect on both economics and political science. The reason for calling the Hotelling model to the reader's attention is to highlight the fact that dynamic processes involving feedback are entirely different from those which occur in his model (in which, as will be seen, there is no feedback).

Alternatives move away from the center of a distribution when an industry generates a good deal of feedback. When large changes in market shares hinge on success in developing a new product, entrepreneurs are likely to impose constraints upon themselves that result in the generation of entirely new alternatives. In the process the probability distributions move to the left if the advance takes the form of cost-reducing discoveries, or to the right if they take the form of quality improving discoveries.

The general picture associated with a series of cost-reducing discoveries is as shown in Figure III. It is assumed that within each period there are hypotheses which will result in both relatively inexpensive and expensive alternatives: hence, the probability distribution. But the entrepreneur does not know where on the distribution a particular hypothesis will fall. An idea that might seem to lie on the extreme left of the diagram when development is started can end on the extreme right side when development is completed. How widely the entrepreneur searches will depend on the amount of feedback generated. When large changes in market shares occur in an industry, the entrepreneur obviously has an incentive to search more widely. On the other hand, when there is no pressure on him, he is likely to search in the region of A. More specifically, he will search until an alternative is found that corresponds with his belief with respect

Figure III

Movements Away from the Center of a Distribution



to the middle of the distribution; then he will stop. This search pattern is associated with an industry that has a hidden hand but no hidden foot, that is, an industry in which changes in market shares are very small. On the other hand, a small degree of rivalry will result in narrow search and a modest degree of movement away from the center of the distribution.

Finally, assume that competitive pressures force firms to set their cost limits at C -- beyond the tail of the distribution. Of course, not all firms in the industry will be equally successful in keeping within the constraint. But on the assumption that one is successful the distributions will move to the left as is shown on the diagram, with the most successful project appearing at the middle of the next distribution. I say "middle," because on the basis of his knowledge of history the entrepreneur can be expected to know that in the next generation of alternatives some will turn out to be less successful than the most successful alternative developed during the previous period. In other words, he knows that the possibility of both good and bad luck must be acknowledged.

It is important to keep in mind, however, that if the entrepreneur hopes to make history he must not assume that he knows the probability that a particular hypothesis will turn out to be successful. To be sure, the entrepreneur will want to make some assumptions with respect to demand conditions (although if he hopes to make as much money as possible he must never assume complete knowledge of the elasticity of demand).[5] Furthermore, he must ask himself some penetrating questions, e.g., why cannot

an alternative be developed to have a 30 or 40 percent advantage over existing alternatives? But never must the entrepreneur assume that he knows how to bring about a discontinuous advance; for if he thinks he knows the answers (even in probabalistic terms) his most precious potential asset will be lost -- his luck. As I argued at some length in my book Dynamic Economics, a Bayesian entrepreneur simply is unable to deal with discontinuous change.[6] He cannot, because to make history it is necessary to generate entirely new hypotheses -- generating a successful new alternative typically involves becoming married to and divorced from a succession of hypotheses. Typically, unexpected problems come up, and new questions must be raised.

Finally, what prerequisite mental attitudes are needed in order to be good at asking searching questions? In whatever field they may happen to be, entrepreneurs must adopt for their operational code, "at close range none of my previous beliefs or theories can be true -- because they are based on probability distributions obtained from previous experiments or experiences." This is the very essence of looking upon an entrepreneur as an open system -- a mind that can interact with its environment to change both its ideas and its environment. However, for the interaction to be successful a good deal of luck is invariably involved.

It is true, of course, that the extent to which people are willing to ask themselves penetrating questions is a matter of degree rather than kind; and for this reason people who ask more or less penetrating questions can be described in terms of their degree of openness. From this point of view, the difference between an entrepreneur and a manager is that the former possesses a higher degree of openness; that is, he is less willing to assume there are sacred truths.

II. CONDITIONS FOR RAPID PROGRESS IN IMPROVING PRODUCTIVITY

The overview of the role of dynamic theory in explaining productivity advances provided in Section I left out of account three important topics. The first is the kind of organization appropriate for bringing about rapid advances, whether productivity gains are measured in terms of reductions in costs or improvements in quality. In the previous discussion it was implicitly assumed that the entrepreneur was the head of the organization. But an entrepreneurial organization contains dozens of entrepreneurs -- dozens of people good at asking questions. While the founders of new firms are invariably the chief question raisers, in older firms this function is not necessarily exercised by the top management. The second important topic to be discussed is dynamic efficiency, which is defined as maximizing the probability of recognizing good luck while minimizing the consequences of bad luck. Finally it is necessary to explain why, if an industry is to continue to generate a large amount of feedback, the more or less continuous entry of new firms is required.

The basic aim of dynamic theory is, of course, to develop testable propositions. To do this a mathematical model is

required which is neither completely stochastic nor completely deterministic, inasmuch as it recognizes the relationship between necessity and chance. Work on this model has only begun. However, to prevent the mathematics from mastering the economics it is necessary to begin with not only economic concepts that can be put in mathematical form, but also some testable propositions (i.e., definite statements which can be shown to be wrong); such propositions will be discussed in the concluding part of this section.

The Role of Organization and Internal Incentives: To possess a high degree of openness an organization must be able to engage in the unconstrained interactions necessary to multiply the possibilities of good luck. It must not only be staffed with imaginative and inquisitive people, it must be highly interactive both within and with the external world -- so interactive that the precise authorship of particular discoveries is always in dispute. Obviously the more interactive an organization, the greater the possibility for encountering good luck. An entrepreneur may be good at asking questions, but if he always interacts with the same people the probability of gaining new insights is most unlikely. As for outside interactions, among others, universities are very important potential sources of new ideas. It is no accident that such interactions were at their peak when most rapid progress was being made in the development of the commercial airplane, new pharmaceuticals, and computers.

Finally, and most important, organizations cannot long remain dynamic if they do not interact with their customers to understand their real problems. In one company whose products have helped bring about productivity gains in several industries, the Minnesota Mining and Manufacturing Company, the key organizational "invention" that played a very important role in its success consisted of having its salesmen, who previously only interacted with distributors, call upon the firms who actually used their newly developed sandpaper to acquire firsthand information about users' problems. Subsequently a research and development organization was set up to see what might be done to make the product more useful. In turn, this activity resulted in the development of completely new products.

How can the openness of organizations be measured? There are several ways. One is as follows: Suppose we collect information concerning an R&D department's telephone calls to find out who calls whom for a period of, say, three months. On the basis of this information we can predict the pattern of communications for the following three months. If our pre are very good we can be quite certain that the organization possesses a low degree of openness. On the other hand, the poorer the predictions that can be made (the greater is the degree of randomness in the calls), the greater is the degree of openness of the department.

Quite as important as the degree of openness is the internal structure of incentives as they relate to getting ahead

in the organization. In general, in dynamic firms the correlation between seniority and salary is low -- with salary not dependent on position in the administrative hierarchy. As an extreme case, there was one chemical company during the 1950s in which twelve highly creative chemists earned more money than the Chairman of the Board. In more static organizations not only does salary depend on administrative position, but there is often a system of fringe benefits which makes leaving the company become more and more expensive. In other words, instead of providing positive incentives for risk-taking, the incentives are better designed to insure obedience.

Dynamic Efficiency: Roughly speaking, my concept of dynamic efficiency is the same as Harvey Leibenstein's concept of "X-efficiency," that is, it is the efficiency associated with producing a given output with fewer inputs.[7] However, while Leibenstein agrees that competition plays an indispensable role in promoting dynamic efficiency, he does not discuss what kind of behavior is involved, nor how it differs from that involved in promoting static efficiency.

The key idea in static efficiency is to make good use of existing knowledge. And, as Adam Smith long ago pointed out in his famous discussion of a pin mill, the main idea in static efficiency is specialization; that is, larger tasks are broken down into smaller and smaller tasks. The organizational corollary associated with static efficiency is not a firm with a high degree of openness: on the contrary, the pursuit of static efficiency inevitably drives organizations to a lower and lower degree of openness.

By contrast, dynamic efficiency involves undertaking research and development and production activities so as to maximize the likelihood of good luck and minimize the consequences of bad luck. The first requirement for a high degree of dynamic efficiency, therefore, is highly interactive organizations to multiply the possibilities of good luck. Second, it is imperative to design exploratory development projects so knowledge can be obtained early in development programs at relatively small cost. Entrepreneurs know from previous experiences that to develop satisfactory alternatives to embody significant advances they will have to become married to and divorced from a succession of hypotheses. As creative engineers are fond of making the point: "It is not what you do not know that can kill you -- it is what you think you know." Hence, the necessity to explore new concepts as quickly and inexpensively as possible.

Third, dynamic efficiency requires that projects be undertaken in a manner that makes relatively easy the incorporation of new knowledge. For example, not only a variable pitch propeller and a new engine saved the DC-3 when it could not meet its performance requirements, its design made relatively easy the changing of engines. To be sure, performance of the DC-3 could have been increased somewhat by closely optimizing the design for a particular engine -- but to do that would have made the

incorporation of new technological ingredients more difficult. Because "saving time" often makes necessary the undertaking of production activities before all uncertainties are eliminated, dynamic efficiency also requires that tooling be undertaken to make relatively inexpensive the incorporation of changes. When introducing new types of commercial airplanes or pharmaceuticals firms do not tool to minimize production costs, but, rather, to minimize the cost of changes.

That rational people behave differently in a world of "strong" uncertainties was, of course, recognized long ago by Keynes when he pointed out that one reason for holding money was to be better prepared to deal with "strong uncertainties"; that is, by holding money one is better prepared to take quick advantage of good luck and minimize the possibility of bad luck. But apparently he did not recognize that the same argument holds with respect to increasing the marginal efficiency of capital. In a world in which knowledge changes the entrepreneur must be sufficiently flexible in planning so that it will be relatively easy to incorporate either new knowledge or newly recognized luck into his plans.

Unfortunately, however, there is a trade-off between static and dynamic efficiency for the reason that organizations cannot be simultaneously optimized for low and high degrees of openness. A highly informal organization capable of responding quickly to new conditions is not ideal for managing well-defined tasks. For example, from the point of view of an automobile manufacturer, firms in the semiconductor industry would be described as chaotic. Conversely, consider the static organizations described by Richard M. Cyert and James G. March in their Behavioral Theory of the Firm:[8] an organization in which not only are primary tasks subdivided into smaller and smaller sub-tasks and the pattern of communications is almost entirely up and down echelons, but search is very narrow: if such an organization were involved, the computer used in Cyert's and March's simulation models could never have been developed.

As a consequence of the trade-off between static and dynamic efficiency the cost of experimentation skyrockets as organizations become more complex and more production oriented. For example, it was for this reason that the Ford Motor Company contracted with the Honda Corporation to set up a small shop at Ford where Japanese engineers worked on the development of a statified charge engine. As a Ford engineer explained it to me: "While Honda still employs the same type of organization we used to develop the Model T, at Ford today our organization is too complex to undertake such a task inexpensively." Apparently engineers at the Ford Motor Company are not convinced about Galbraith's argument that making major advances requires massive organizations.

The trade-off between static and dynamic efficiency also can be observed in the declining ability of American industry to engage in foreign competition. This trend cannot be blamed upon the U.S. disadvantage in terms of scale economies or vertical

integration, that is, on a disadvantage in static efficiency. In terms of static efficiency we are still well ahead of the other industrialized countries. The problem, rather, is that organizations optimized for a high degree of static efficiency are incapable of highly flexible responses. In fact, as compared with the steel industry, the Defense Department may be regarded as a relatively flexible instrument.

Thus, economists who continue to revere scale economies and vertical integration are worshipping monuments of the past. The exploitation of such economies involves massive organizations with a minimal ability to respond to new circumstances. By contrast, from the standpoint of dynamic efficiency small is to be regarded as beautiful.

The Role of New Entrants into an Industry: There is an abundance of evidence that entrants into an industry -- whether the meat packing, automobile, aircraft engine, radio, or the semiconductor industries -- have played an indispensable role in maintaining the dynamism of the industry in question. Because new firms have great incentive to be different, they create rivalry which increases the incentive to take risks in the entire industry. Existing firms become fairly quick to adopt ideas which they earlier would have dismissed. Or to put the same point in another way, the principal cause of the railroad cartels breaking down again and again during the nineteenth century was the entrance of new firms into the industry.[9]

Contrary to common wisdom, railroad companies desired regulation not because the government was more efficient in running a cartel, but because regulation was needed to put an end to the entry of unobedient new firms.

To be sure, I am not the first to point out the role of new firms in providing an industry with a greater incentive to engage in risk-taking. For example, the same point is made in F. M. Scherer's book, Industrial Market Structure and Economic Performance.[10] However, while it is true that the incentives of new firms differ from those of well-established firms, the former have an even more profound advantage inasmuch as they can exhibit a greater degree of dynamic efficiency.

On the basis of the concepts discussed in the previous two sections, the reasons for their relative advantage in dynamic efficiency should be fairly apparent. If a firm is to exploit the discoveries it has already made, it is almost inevitably driven to a higher degree of organization; that is, it becomes less interactive and, as such, possesses a lower degree of openness. As in writing a book, there must be an end to generating new ideas if you hope to finish it; like it or not, you must impose a high degree of organization on yourself. Moreover, it should be kept in mind that once a firm is driven to a higher degree of organization the reference scales of its members change; that is, an advance of a particular size seems larger than before. For example, when executives of the Ford Motor Company describe the Mustang as a fundamental breakthrough they are describing an

organization whose reference scale is not as large as it was in 1908. Or, to put the same point in psychological terms, when organizations become more and more structured, the tolerance of ambiguity of their members is likely to decline to the point that small differences appear to be large differences.

By contrast, new firms tend to be rather informally organized; and typically their members have not known each other very long. Indeed, in some cases the key ideas are roughly formulated even before the firm is established. Moreover, after the organization is established, internal competition mainly takes the form of competition in ideas. Only later does position in the organizational hierarchy become the chief form of competition. In short, this kind of environment is ideal for luck to play an important role; and the advantage of new firms is mainly one of openness. Moreover, successful new firms (and many of them are not successful) pay a good deal of attention to understanding the real problems of their customers. It is only in well-established firms in which the R&D process has become highly routinized that inventiveness for its own sake becomes the order of the day.

To be sure, there are exceptions to the rule that as a firm exploits its discoveries its openness declines. Consider, for example, the field of communications satellites. Each new generation of communications satellites contains some very significant advances. The people who bring about these advances describe their jobs as discovering loopholes in the laws of nature. However, to be successful a new communications satellite must not only embody some marvelous new ideas, it must also be a highly reliable system. Consequently, sooner or later everyone on the team must stop being an entrepreneur and do his best at being a manager. In other words, precisely the same thing happens in this field of development as happens in others. The difference is simply that once the satellites are in orbit there is no way to bring about further improvements. Consequently, the teams are disbanded and once again managers become entrepreneurs.

There are, of course, in other industries a few far-sighted research managers who operate in much the same way. But, statistically speaking, these exceptions seem to be quite unimportant. Typically, if an entrepreneur becomes a manager, say, for a period of three years, he seldom reverts to the status of an entrepreneur.

There are, of course, other advantages of a new firm. As was already noted, the cost of experimentation is likely to be a good deal lower. By not having a well-established techno-structure a new firm is less likely to bring about discoveries resulting in their own destruction. Nor need relatively newly established firms feel as constrained as well-established firms when making discoveries that will make highly specialized facilities obsolete.

In summary, new firms play a double function. They not only increase the incentives to take risks in an industry as whole; they keep the openness of the well-established firms from declining. Shrinkages in reference scales of well-established firms are prevented by the fact that as long as new firms

continue to enter an industry the longer established ones must be constantly prepared for surprises. To be sure, this does not apply to all new firms inasmuch as some are content to find comfortable niches. The previous discussion was concerned with firms that aspire to become major factors in an industry.

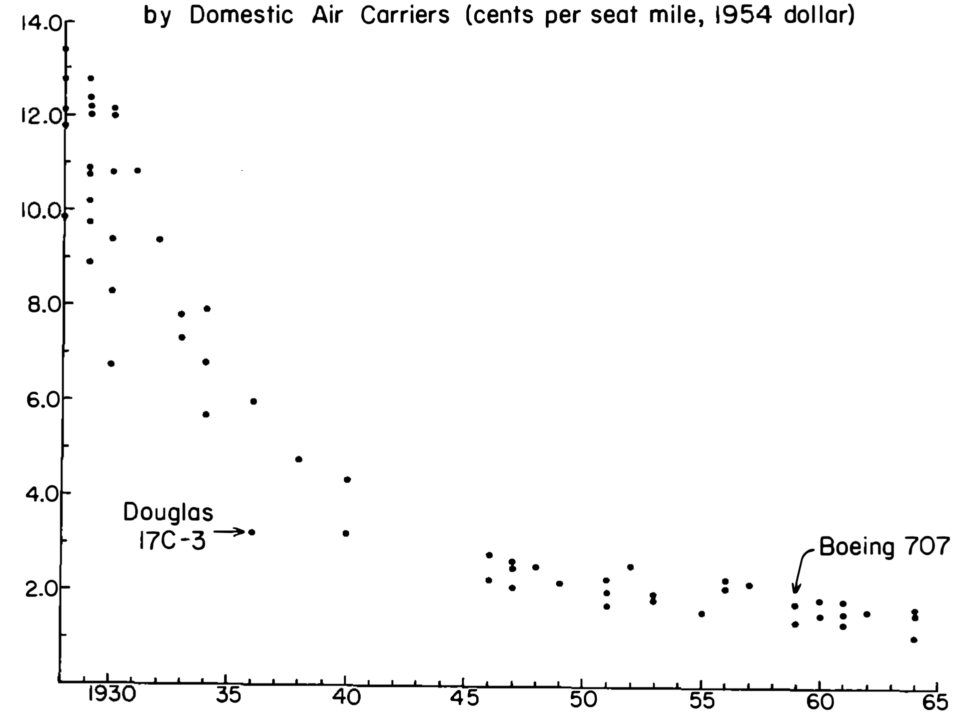
<u>Toward a Dynamic Model</u>: Now that we have discussed the principal ingredients of dynamic theory, I will turn to the task of formulating a predictive theory. To do this it will be useful to make explicit two concepts that were implied in the previous discussion: Types I and II uncertainties.

Type I uncertainty implies risks for firms, and inasmuch as they cannot buy insurance to protect themselves from such risks, it provides an incentive to deal with them. And, as already indicated, insofar as Type I uncertainty arises from competitive risks, it is measured by the degree of change in market shares. Consider, first, the case in which firms are already insured against competitive risks -- the case of a perfect cartel in which changes in market shares occur within very narrow limits. There are only trivial differences between products, and when products are changed, the changes are trivial. In such a situation firms can make nearly perfect predictions of each other's products; and there is a negligible degree of Type I uncertainty, because there is a negligible amount of feedback. But, as firms take greater and greater risks, changes in market shares will become greater and greater; and as more feedback is generated Type I uncertainty increases. It should be kept in mind, however, that from a somewhat different point of view a high degree of uncertainty does not necessarily imply real surprises. Assume that every three or four years one or another firm in the industry generates a significant discovery. In this case the firms in the industry cannot predict each others' products, but they can predict a surprise! However, they are not necessarily startling from the point of view of insiders whose reference scale has made them accustomed to highly discontinuous changes. Thus, from the point of view of an industry unaccustomed to dealing with the unexpected, even a relatively small deviation from the "normal" will be regarded as surprising. For example, when in the successive breakdowns of the railroad cartels during the 1880s rates fell by as much as 20 percent, the railroad companies described this as a "price war." On the other hand, in the commercial aircraft industry during the 1930s or in the semiconductor industry until fairly recently where a 20 percent advance was regarded as an incremental improvement, if a firm's rivals behaved like the railroads that would not have been regarded as war; it would have been regarded as peace!

The main point to keep in mind is that when the hidden foot is doing a good job of keeping Type I uncertainty high, it operates quite as automatically as the hidden hand. For example, as Figure IV shows, progress in reducing the operating costs (including depreciation) of commercial airliners was so smooth that it almost seems to have been preordained. Moreover, as the Figure shows, during the period between 1925 and 1940, when progress was most rapid, it was also most unpredictable, because

FIGURE IV

Estimated Operating Costs per Seat Mile for Aircraft Used by Domestic Air Carriers (cents per seat mile, 1954 dollar)



Source: Almarin Phillips, Technology and Market Structure (Heath Lexington-Borhs, Lexington, Mass 1971) pp.50-51.

both good and bad luck played an important role in outcomes. During that period the difference between the high and low cost alternatives of the alternatives developed each year averaged over 50 percent.

After World War II there was a definite retardation in the rate of progress. This, however, is not difficult to explain. In the first place, rate regulation of the airplane companies (which was established in the late 1930s) had the effect of taking the pressure to reduce costs off the aircraft developers. In the second place, during the 1930s entry of new firms into the industry came to a standstill. Indeed, one of the most important reasons for deregulating the airline industry is that as a consequence of a greater degree of rate competition aircraft companies will find themselves under more pressure to reduce costs.

Another way to measure Type I uncertainty is in terms of the probability of a good or bad surprise. Table I shows the fate of 26 major automobile firms during the period 1903 to 1921, and 31 semiconductor firms during the period 1957 to 1975. It should be noted that of those automobile and semiconductor firms in the top five not all remained so for the entire period -- only one automobile company and one semiconductor company held that distinction. The principal difference between the two industries with respect to downfalls is that in the automobile industry they were more severe. In the automobile industry all of the unpleasant surprises involved either dropping to 10th place or going out of business. On the other hand, in the case

TABLE I

FATE OF 26 MAJOR AUTOMOBILE FIRMS
1903-1924

Never fell from top 5	3 firms
Fell from top 5	6 firms
Rose into top 5	2 firms
Remained minor entities	15 firms

Source: Dynamic Economics, p. 100.

FATE OF 31 SEMICONDUCTOR FIRMS
1957-1975

Never fell from top 5	3 firms
Fell from top 5	5 firms
Rose into top 5	1 firm
Remained minor entities	22 firms

Source: The Semiconductor Industry: A Survey of Structure, Conduct and Performance, January 1977, p. 23.

of the semiconductor industry a typical downfall involved something like a 50 percent decline in a firm's share of the market. Of the automobile firms who made it into the top ranks or who remained in the top ranks, only one was in business as early as 1903, two entered the field in 1916, and two in 1915. In the semiconductor industry, too, newcomers played much the same role.

It should be apparent from these data that the successful princes in modern industry cannot be defined as firms that, if they started out by being lucky, spent more on R&D, thereby increasing the probability of further success. Rather, like many of Machiavelli's princes, many of the modern princes met their downfall because they could not adapt to new circumstances.

Finally, it should be pointed out that competition from other industries or from foreign firms can play an important role in generating feedback for an industry and, hence, in making Type I uncertainty reasonably high. Moreover, it should also be pointed out that firms can face a high degree of Type I uncertainty for reasons other than competition; in particular, uncertainty with respect to inputs can play more or less the same role. For example, some petroleum companies are in a much poorer position than others with respect to oil reserves, and for this reason are more dynamic than the other petroleum companies. Or, to take a more extreme example, because of input uncertainty Japanese steel firms have a far greater incentive to engage in dynamic behavior than do American steel firms.

While Type I uncertainty provides firms with challenges, Type II uncertainty provides opportunities. To clarify this concept of uncertainty it will be useful to distinguish between three states of the world. The first is a completely predictable world in which chance plays a zero role. For example, in general equilibrium economics the entrepreneur is assumed to know the final equilibrium price before any trading takes place. In such a completely deterministic world entrepreneurs have no opportunity whatsoever to be lucky. Secondly, we can consider a world in which entrepreneurs can make predictions of each other's actions in probabalistic terms. However, while chance can play a role in this world, it is a completely prescribed role, because it does not acknowledge the probability of events not included in an initial subjective probability distribution. Finally, we can consider a world of strong uncertainties -- a world in which the uncertainties cannot be measured in terms of probability distributions, because quite unexpected events do occur -- this is a world in which the stronger the uncertainties, the greater the roles likely to be played by both good and bad luck.

Such uncertainty is measured in terms of the variance of outcomes of research and development projects. A high variance outcome indicates that entrepreneurs recognize the possibility of opportunities. A low variance implies that entrepreneurs have stopped asking sharp questions. For example, in the discussion of aircraft operating costs we saw that during the period of rapid progress the difference between the lowest and highest cost alternative averaged about 50 percent. Such outcomes imply a high degree of Type II uncertainty. On the other hand, a 10 percent difference would imply a low degree of uncertainty.

As is implied by the previous discussion, the relationship between Type I uncertainty and Type II uncertainty is simply this: when Type I uncertainty increases we can expect to observe that at some point an industry will respond to the increase in feedback by (1) creating more favorable internal incentives for risk-taking; and by (2) acquiring a greater degree of openness (as measured by the randomness of the internal and external communications). The consequence of bringing the internal organization into a greater degree of harmony with its external environment will be to speed up the rate of progress. In particular, if the rate of progress is measured in terms of cost reductions we can expect to observe a more rapid rate of progress. On the other hand, when Type I uncertainty declines just the opposite occurs with entrepreneurs tending to pose less searching questions, with luck playing a less important role in R&D outcomes, and, therefore, with a lower rate of progress. In other words, we can expect to observe an S-shaped curve with a period of rapid progress in moving alternatives away from the center of a distribution (fast history) followed by a period of slower progress (slow history). However, as will be brought out in the next section, the predicted responses to an increase in the degree of Type I uncertainty are of a very different character from the predicted responses of a decline, as different as waking up is from going to sleep.

Let us suppose that we are dealing with the second kind of situation -- a decline in Type I uncertainty. When fast history turns into slow history how can we be sure what is cause and what is effect? Are firms merely responding to a decline in their opportunities -- or are the opportunities declining because the degree of openness is becoming smaller and smaller? There are two fundamental reasons for assuming that the basic explanation is to be found in a declining degree of openness brought about by the failure of new firms to enter the industry. The first is an empirical reason. Assume that the industry in question is experiencing slow history -- that it is on the relatively flat portion of an S-shaped curve -- and a discovery comes along to provide an acceleration in the rate of progress. Now, if the rate of progress were limited by opportunities we would expect that major firms in the industry would account for their share of revitalizing discoveries. But they do not. Of 50 such cases about which I managed to find evidence all the revitalizing discoveries came either from a new firm in the industry (e.g., the Polaroid camera), a firm from another industry (e.g., diesel locomotives, synthetic fibers), or from a university laboratory (e.g., computerized machine tools).[11]

The second and more basic reason a decline in opportunities is not a fundamental cause of slowdowns is that the phenomenon of diminishing returns is not applicable where ideas are concerned. To be sure, if a technology is defined narrowly enough, for example, if railroad transportation is defined to include only the possibility of steam engines, it can be predicted that sooner or later the rate of progress will diminish. However, if the definition of a technology is more or less continuously broadened there need be no decline in the rate of progress. Or, to put the same point another way, assume that the conditional probability of one or another firm being lucky in a present time period (say, a period of three years) depends on the degree of luck realized during previous time periods. In other words, assume that a good idea can help pave the way for more good ideas. Now it is true, of course, that in the present time period no firm may be lucky. But as long as it is assumed that the probability of luck in a given period is not independent of the degree of luck realized in previous periods, the slope of the curve relating the rate of progress to time will remain the same: that is, under this assumption opportunities would never vanish and the rate of progress in an industry would never slow down! But typically, the rate of progress does slow down -- and what reason can be given for the slowdown other than a decline in challenges?

To be sure, insiders will not necessarily agree with this point of view. On the contrary, they can be counted upon to insist that progress is slower because bringing about impressive advances had become enormously more difficult; and in one sense they are absolutely right. A more constrained environment will make bringing about such advances more difficult.

RESPONSES TO INCREASES AND DECLINES IN THE DEGREE OF TYPE I UNCERTAINTY:

Let us assume that firms have become accustomed to dealing with either a low or high degree of Type I uncertainty, as the case

may be. Further, let us assume that the difference in feedback is reflected in the internal characteristics of firms: that is, those accustomed to dealing with a high degree of feedback will feature more favorable incentives for individual risk-taking and more diverse internal and external interactions. To be sure, some firms may be unwilling or unable to bring their internal characteristics into tune with the signals from their external environments. However, if a serious discrepancy occurs for many years it is quite unlikely such firms will survive.

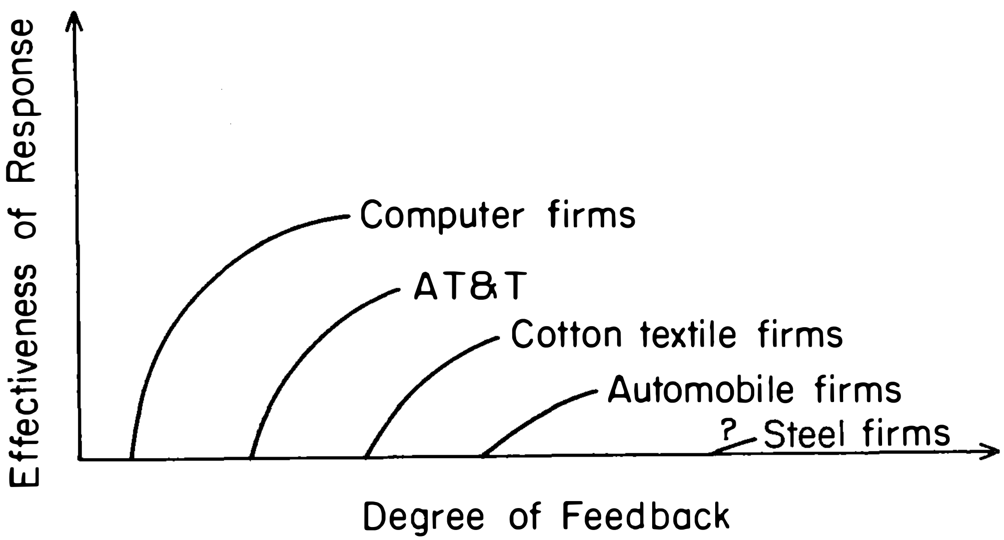
The first part of this section will deal with responses to increases in the degree of feedback. In dynamic economics response is measured in terms of outputs rather than inputs. At the one extreme there is the response that is so rapid and so effective that the firm or firms in question experience no serious decline in market share. Conversely, there is the response that is so delayed and so weak a decade must pass before the decline is somewhat arrested. However, it can be assumed that response is non-linear because the more entrenched the internal technostructure, the more cohesive the internal alliances, the greater amount of feedback that will be required to ellicit any response.

Statistically speaking, however, there is good reason to assume that the speed and effectiveness of a firm's response will be highly correlated: inasmuch as both are dependent upon its internal characteristics.

Much empirical work remains to be done before economists can develop reliable dynamic reaction functions. However, on the

Figure V

Dynamic Response to Additional Feedback



basis of fragmentary information, I have made some rough guesses of the likely differences between dynamic response curves for firms from several industries; these are shown in Figure V. The reader may be surprised by the fact that AT&T appears on the diagram. Most people think of AT&T as a monopoly, and of Bell Telephone Laboratories as an organization which for many years has remained highly dynamic without the need of a hidden foot. In short, it seems that in this case we have found an almost perfect example of Schumpeter's dream of the day when progress would become quite automatic.

This quite commonly held belief about AT&T is wrong.[12] In the first place, informed people are in agreement that Bell Telephone Laboratories was not nearly as dynamic an organization in the period before World War II as it was after. In the second place, it is not difficult to explain the rise in its dynamic behavior. In addition to the minor challenges with which AT&T dealt before World War II, after World War II it encountered three major ones. During the late 1940s several firms became interested in using microwave systems as a relatively inexpensive method of long-range communications. These included both television companies and large corporations that wanted to establish their own communication networks. The technical response to these threats was development of the TD-2 microwave system. The nontechnical response consisted of arguments before the Federal Communications Commission (FCC) that common carrier capacity was large enough for all needs. The FCC ruled in favor of AT&T with respect to television signals, but ruled against it with respect to private users of microwave systems. Second, in the early 1960s the Hughes Corporation was able to persuade Congress that its communications satellite system was a better bet than the Early Bird satellite developed by AT&T. Moreover, when the Hughes' system turned out to provide a less expensive alternative than transatlantic cables for international telephone calls, AT&T suddenly found itself faced with a greater threat. However, it was able to persuade the FCC that a mixed system of satellites and cables was best. As it has shown in several decisions, the FCC is willing to permit outsiders to compete with AT&T for new services. But for a regulatory agency to allow a new alternative to result in the creative destruction of a somewhat older one is almost unthinkable. Finally, in the 1960s a new series of threats arose when Microwave Communications, Incorporated (MCI) proposed to act as a common carrier for private owners of communications systems. In 1969, six years after MCI's application was submitted, the FCC approved. Shortly afterward the FCC was flooded with thirty applications by firms that wanted to establish themselves as one or another kind of common carrier. AT&T's response was to offer to private users a competitive system (Data Under Voice) that was more reliable and could provide a significant cost savings.

In short, there can be no doubt whatsoever that the hidden foot -- often in the form of attacks by relatively new firms -- played a major role in explaining why Bell Telephone Laboratories became a more dynamic organization after World War II. One principal difference between AT&T and General Motors is that

having a relatively unstructured organization in the form of Bell Laboratories as well as a more structured organization in the form of Western Electric, AT&T has a substantial advantage in its ability to deliver a quick technological response to additional feedback. On the other hand, by being regulated by the FCC it also has an advantage in getting the rules of the game modified when its technological prowess does not suffice. For both of these reasons, competitive inroads into AT&T's markets have been held to something like 5 percent of her business, while during the period 1955 to 1975 the share of the automobile market accounted for by foreign cars rose from about 5 to well over 20 percent.

If AT&T made its decisions in terms of the longer-run interests of its stockholders, it would not try to protect Bell Telephone Laboratories and Western Electric from outside competition. It would welcome such competition with open arms!

Figure V shows cotton textile firms having a greater dynamic response capability than automobile firms. The reason is, based on fragmentary data, it appears that in response to the threat from synthetic fibers cotton textile firms moved forward faster and more effectively than did the automobile industry in dealing with its foreign competition. As for American steel firms, while they are certainly less dynamic than automobile firms, how much less dynamic is an open question. No one knows the amount of additional negative feedback that would be required to wake up the steel industry.

When firms respond to a sharp and persistent increase in the degree of negative feedback very often the ideas needed to respond are not lacking; that is, they are ideas that entrepreneurs far down in the organization hierarchy have been trying to sell to the vice-presidents. On the other hand, when ideas are lacking, the entrepreneurs will typically begin to search outside the organization while the vice-presidents are still busily engaged in convincing each other that the decline in market share is only temporary. However, sooner or later one of the more adventurous vice-presidents will begin communicating with the entrepreneurs; and after an organizational struggle new coalitions will be formed. In short, when the internal power structure is not so completely cemented together that it is quite insensitive to feedback, the predicted organizational response is a greater diversity of internal and external interactions. Moreover, while internal incentives may or may not be changed, it can be assumed that those who are successful in taking risks will be rewarded.

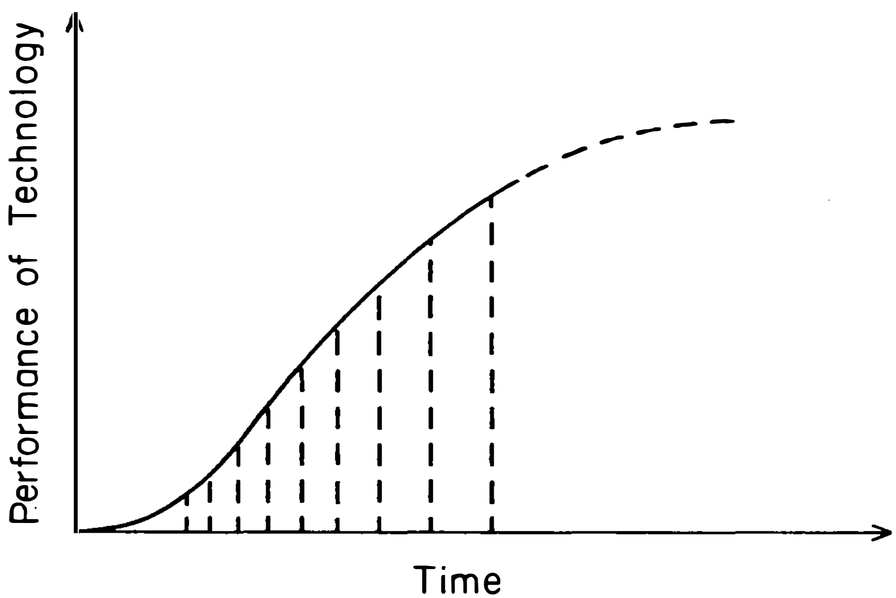
Next, let us turn to the case of a persistent decline in Type I uncertainty. Such a decline might occur because an industry was able to gradually reduce uncertainty with respect to its inputs. But, let us suppose that the cause of the decline in question is a reduction in feedback brought about by the fact that new firms are not entering the industry at the rate they once were. In order to better describe the process, a concept will now be introduced that plays a central role in dynamic economics: the distinction between micro- and macrostability. An industry with a high degree of microstability is a highly

predictable industry: market shares remain approximately constant, there is a relatively small degree of variance in the outcomes of research and development projects, and the pattern of communications within the associated firms is highly predictable. Good examples are provided by the Swiss chocolate and the Scottish textile industries. Conversely, inasmuch as it is concerned with the ability of an industry as a whole to make smooth adjustments to new circumstances, macrostability is a dynamic concept of stability. The degree of macrostability is measured by the rate the performance of a technology improves, whether measured in terms of reductions in costs or improvements in quality.

A good example of an industry possessing a high degree of macrostability is the U. S. semiconductor industry. Assume that we can devise a satisfactory measure of the rate of technological progress. Then, up until about 1970 the picture was that of a rapidly rising portion of an S-shaped curve, as shown in Figure VI. The vertical lines on the curve represent major discoveries such as the silicon junction transistor, the tunnel diode, the Planar transistor, the integrated circuit, and so forth. Viewed as isolated events these discoveries were quite unpredictable. That the entire process was both rapid and smooth indicates an industry in which there was a good deal of feedback.

However, as a technology matures scale economies and vertical integration become more important. For example, the difference between Texas Instruments today and Texas Instruments in, say, 1955 is more or less the difference between General

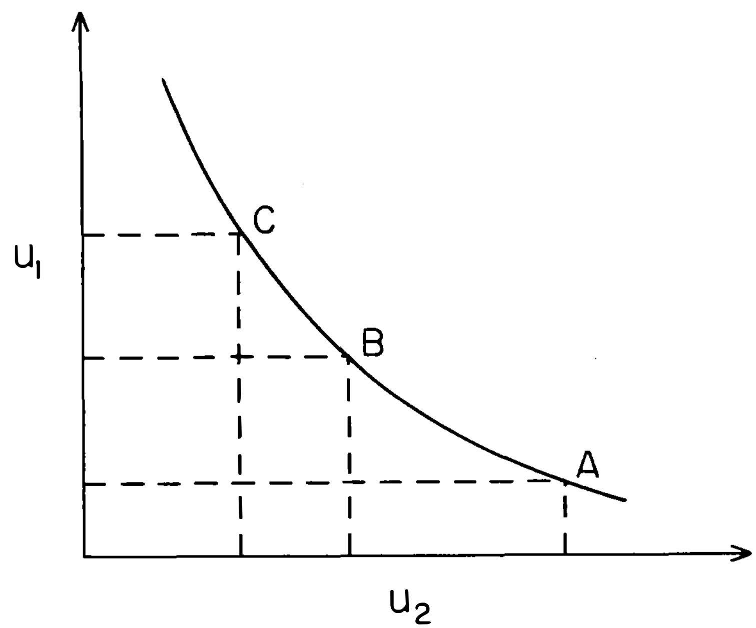
FIGURE VI
A Macrostability Decline



Motors in 1908 and General Motors in 1920. As a consequence, if a new firm wishes to enter the industry on the same basis as a well-established firm, it is likely to find that the cost of entry has increased by an order of magnitude. This is not to say, of course, that even with higher entry costs new firms cannot enter. But it is to say that the potential entrepreneurs must be very clever not only in generating new ideas, but in persuading somebody to provide the risk-capital. Consequently, as a technology matures the probability of new firms entering an industry is likely to decline very substantially -- and as entry declines so will the degree of macrostability.

When entry into an industry slackens the degree of macrostability as measured by the rate of progress as shown in Figure VI will decline. As long as new firms enter an industry we can assume that from a micro point of view outcomes will be highly unpredictable, whether measured in terms of the outcomes of research and development projects or changes in market share. On the other hand, we can also be fairly certain that as long as this situation exists the continuation of rapid progress will be highly predictable. Let U_1 be the uncertainty with respect to the continuation of the steeply ascending portion of the curve shown in Figure VI; and let U_2 be the degree of uncertainty with respect to micro outcomes (i.e., Types I and II uncertainties). Then, as is shown in Figure VII, a low degree of uncertainty with respect to the continuance of the fast history trend implies a high degree of uncertainty with respect to micro outcomes (A). However, as more and more certainty is introduced into micro

FIGURE VII
Trend Uncertainty versus Types I and II Uncertainty



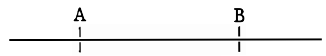
outcomes (due to the failure of new firms to enter the industry), continuance of the previous rate of progress becomes more and more uncertain (as we go from A to B and from B to C), which is to say, we can predict that sooner or later the rate of progress will decline.

The two most important differences between increases and declines in Type I uncertainty are the following: First, whereas the former involve highly discontinuous responses, the latter do not. As entrepreneurs are phased out of the operation managers acquire an ever more important role. Second, when Type I uncertainty declines, changes in incentives and organizational characteristics are much easier to measure. Indeed, even without any measurement, it is not necessary to be a social anthropologist to discern what is happening.

Finally, let us assume that no new firms enter the industry in question for, say, a period of 10 to 20 years. What kind of equilibrium will be ultimately reached, and what is the nature of the process when a dynamic equilibrium collapses into a static equilibrium? To answer these questions requires consideration of the following topics:

1. Movements toward the center of a distribution that result in trivial differences in products.
2. The reasons the final equilibrium is likely to be stable.
3. Why, when a dynamic equilibrium collapses, the path is likely to be highly predictable.

Suppose that the time is 1965, when the demand for gasoline was relatively inelastic with respect to small changes in price. And also assume that initially two gasoline stations are located on a line in a manner that would minimize transportation costs for the buyers, that is:



However, while this is a quite satisfactory situation from the standpoint of the consumer, it is not from that of the gasoline stations' owners. To be sure, the customers to the West of A and to the East of B represent a captive audience, so to speak. However, inasmuch as A can increase the size of his captive audience by moving closer to the center, the possibility of higher profits will pull him in that direction. However, when this happens B receives negative feedback. And to reestablish his market position he must move toward the center. A partial equilibrium is reached when the gasoline stations are on adjacent corners. To be sure, if the cost and services were indistinguishable, one station could cut prices in order to draw customers away from the other's territory. But, let us assume that to minimize the probability of such behavior each gasoline station offered a slightly different product, and that the gasoline station attendants learned to recognize the idiocyncracies of their various customers. When this happens markets will be shared, and we will be in a static equilibrium in respect to both geographical and product space. Moreover, the same forces will draw other business firms to the center of the line. Consequently the final

equilibrium position is one in which there is a clustering of business firms with feedback no longer playing a significant role.

What if demand were elastic with respect to the cost of transportation? Under this assumption firms located in the center would lose business of customers located on the extremities of the distribution. Moreover, as people move into the outlying areas the losses would become greater and greater. When this occurred new clusterings would appear in the more and more outlying areas.

In order to observe the same tendencies at work with respect to national markets, we obviously must define product space in a somewhat different manner. For example, consider the automobile industry during the 1950s when foreign competition provided a negligible amount of feedback. At that time competition took place mainly in terms of style. And, while it is an open question to what extent automobile markers created a taste for style or merely responded to such tastes, the fact of the matter is that firms that failed to recognize a change in style, and, hence, a new movement toward the center were seriously penalized. For example, Chrysler, which was very slow to adapt to long tailfins, found that from 1952 to 1954 its sales had declined from 20 percent to 12 percent of the market. In other words, it paid more or less the same price for ignoring Hotelling's law as did Senator Goldwater.

Another dimension of commodity space is conspicuous consumption or Veblen space. For example, for many years one could buy a nearly identical Ford or Chevrolet intermediate car, with more or less the same options, depending on his preferences. But depending on his preference for conspicuous consumption, he could buy essentially the same automobile with the same options in the form of a Mercury or a Buick.

It must be emphasized again that movements toward the center of a distribution assume an industry in which there is a negligible amount of feedback. Consequently, after some minimum threshold in rivalry has been reached, Hotelling's law will cease to make good predictions, which is to say, alternatives will be driven away from the center of a distribution. For example, as a consequence of being quicker to borrow ideas formerly found in foreign cars, the 1979 General Motors intermediate cars are significantly different automobiles from the corresponding Ford and Chrysler cars. However, inasmuch as the share of the automobile market accounted for by foreign firms rose from less than 5 percent during the 1950s to over 25 percent during the 1960s, we certainly can predict that at some point the industry will respond to more feedback; and the response will take the form of making the alternatives look less alike. Moreover, we can also predict that for such a response to have occurred the inner pattern of alliances within General Motors must have changed. Without becoming a more interactive organization, it simply could not have responded to the additional feedback in the manner it did.

To return to the discussion of the nature of a Hotelling

equilibrium, it should be apparent that even in the case of a single product, differentiation can take many different forms, some very subtle. Moreover, we can assume that when feedback is lacking product differentiation will take on a variety of forms. When the name of the game is to minimize the probability that a rival will engage in price cutting, it pays to recognize both the idiosyncrasies of particular consumers and the differences between consumers. Therefore, whereas Hotelling's model dealt with only one type of product variation (making cider more or less sweet), it must be acknowledged that in the real world many distinctions between products will be made. To be sure, scale economies will limit the extent to which a product can be tailored for a particular consumer. But taking scale economies into account, firms try to go as far as possible in recognizing individual differences in tastes. For example, in an excellent article on the ready-to-eat breakfast food industry (an industry no new firm has entered for some years), Richard Schmalensee has in effect extended the Hotelling argument by taking up a case in which the variations include differences with respect to sweetness, protein content, shape, grain base, and crunchiness.[13] According to his argument, firms in the industry went about as far as they could in recognizing these differences -- with the consequence that price cutting has rarely occurred. However, whereas the firms in the breakfast food industry were good at recognizing differences in tastes, they were apparently not nearly so expert in detecting changes in tastes. When natural health foods became popular during the early 1970s, quite a number of new firms entered the market; only after that did the well-established firms respond to the change in demand conditions. In fact, even when demand conditions are fairly well-known, established firms are often slow to recognize changes in tastes. Consider, for example, the long time elapse before the hamburger chain restaurants began to provide more variety in their menus.

Why, when reached, is a Hotelling equilibrium likely to be very stable? The essential reason has already been given; namely, when firms no longer have to deal with feedback they lose their ability to engage in anything but routine tasks. To be sure, calcification does not occur immediately; it often takes 5 to 10 years. As it occurs the obvious response of firms is to protect themselves from feedback. Consequently, they engage in product differentiation and advertising. However, while product differentiation insures firms against small price cuts on the part of their rivals, it obviously does not against the possibility of a large cut. Under what circumstances are large cuts likely to occur? A firm might cut its prices and profits to drive another out of business. But price wars do not occur often. On the other hand, a firm might be quite willing to reduce its prices if it can bring about (or has brought about) a quite significant reduction in its costs. But calcified firms are not likely to be able to reduce their costs significantly. Hence, a Hotelling equilibrium is very stable inasmuch as it minimizes the probability of either small or large price cuts. What makes it stable is that a firm

is not likely to start a war it cannot finish. Hence, such an equilibrium can be described as a system of stable mutual deterrence.[14]

However, it is important to keep in mind that, while such an equilibrium is stable from the point of view of the Captains of Industry, it is not necessarily stable from the point of view of potential entrepreneurs in firms, who enjoy bringing about discontinuous advances. Moreover, from their point of view (as distinct from the point of view of the top leadership), when the Oldsmobile Division is able to reduce the Buick Division's share of the market, that is something like winning in the Olympics. Hence, to curb these troublemakers who would disturb the peace, the main posts are given to trustworthy managers, incentives are developed to discourage risk-taking, and formidable rules and regulations are developed to make any and all change difficult. In brief, while a Hotelling equilibrium is stable from the point of view of the top management, company regulations are required to maintain the peace.

Finally, the path toward a Hotelling equilibrium is likely to be highly predictable, because it involves self-prophesizing changes in expectations. Assume that an industry is in a dynamic equilibrium because of the entry of new firms. To be sure, the new entrants and the well established firms will not behave the same. But, assuming that every firm has adjusted its behavior to deal best as it can with this degree of feedback, from a technical point of view that can be described as a Nash equilibrium:

an equilibrium in which the strategies of firms are jointly consistent. However, a Hotelling static equilibrium can also be so described. The difference between the two equilibria is that one generates a high degree of feedback while the other generates none. This, in turn, means that whereas in the first equilibrium alternatives will be veering away from the middle of a distribution due to the generation of new ideological mutations, in the second, alternatives will be moving toward the center of a distribution, with mutations becoming less and less significant.

When entry of new firms stops, so does the principal means of bringing new ideas into the industry. Selection of top managements either from within the firm or within the industry insures that product differences will be minor.

Another way of describing the collapse of a dynamic equilibrium is as a collapse of expectations. Whether an industry is in a dynamic or static equilibrium expectations will remain the same. But, in going from one equilibrium to the other expectations do not remain the same, because where in the first case they are premised on continuing surprises, in the second they are premised on remaining unsurprised. The change in expectations occurs, because when new firms discontinue entering an industry, established firms will find that their expectations with respect to surprises have been underfulfilled, and as they continue to be less surprised, their expectations and behavior will change. Thus, not only is a Hotelling equilibrium very stable, but because of its self-prophesizing character the path from a dynamic to a static equilibrium is almost as predictable as death and taxes.

Limitations of Dynamic Theory: Although it is my conviction that only by taking feedback into account can economics become a predictive science, a few words are in order about the limitations of dynamic theory.

First, in making predictions we do not pretend that individual discoveries can be predicted. Dynamic economics is not concerned with making microscopic predictions. Rather, it is concerned with making macroscopic predictions -- predictions of the rate of progress as a function of the degree of Type I uncertainty.

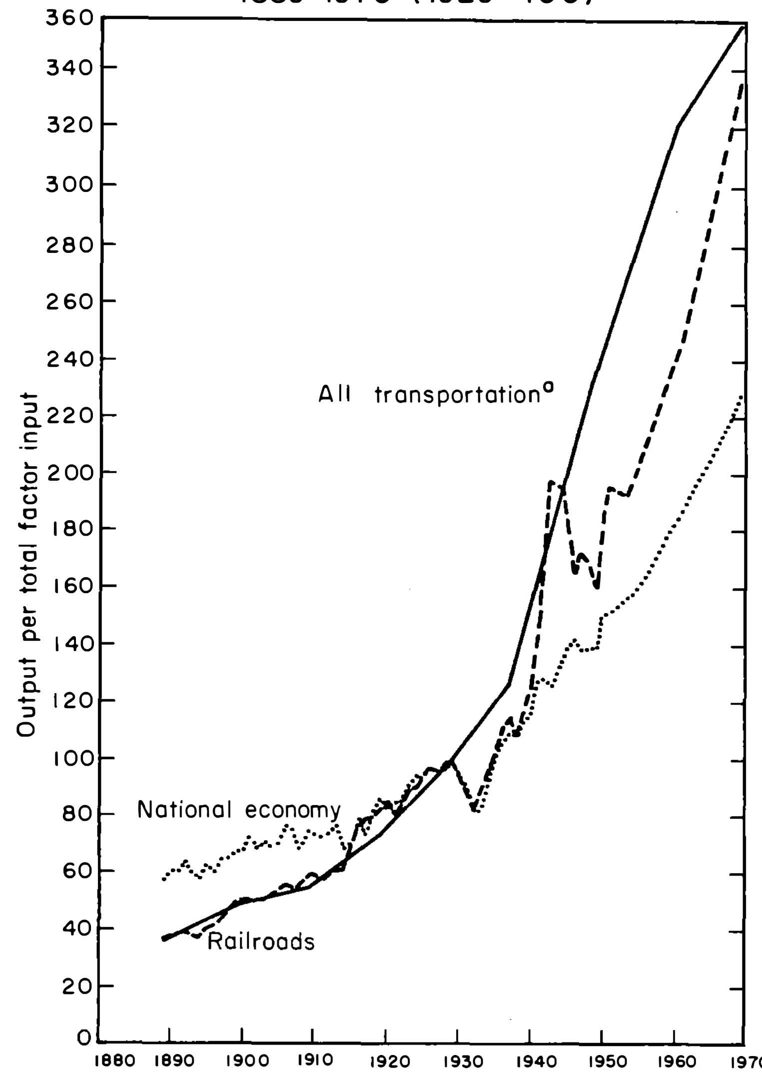
Second, it should be apparent that once the rate of progress in a particular industry has leveled off, it is not easy to predict the dynamic response to increases in the degree of feedback. To be sure, empirical work relating increases in the degree of feedback to the dynamic response will enable us to make better predictions. However, inasmuch as a few key people can often make a significant difference with respect to the timing of the response, it might never be possible to make really good predictions.

Third, dynamic theory does not permit us to make comparisons across industries; that is, we cannot infer that progress is higher in one industry than another because of differences in the degree of feedback. The reason is simply that in some industries it is easier to broaden the definition of the technology (e.g., as jet engines broadened the definition of aircraft technology; as Bessemer steel broadened the definition of steel technology; as semiconductors broadened the definition of computer technology).

For example, in railroad technology the rate of advance in total factor productivity has been very respectable. As Figure VIII shows, in the railroad industry its average rate of increase was not as great as transportation as a whole; but it was greater than for manufacturing in general. Moreover, it should be noted that although railroad technology is very old there is no evidence of retardation in the rate of productivity increase.

Nevertheless, it can also be said that were it not for regulation progress in reducing costs would have been faster. In general, the effect of economic regulation is that by stabilizing market shares feedback is removed from industries and, therefore, they have no incentive to be quick to adopt new ideas. Consequently, the rate of diffusion of new advances in the railroad industry has been very slow. According to estimates made by Edwin Mansfield, once one railroad adopted an invention it took a long time before the industry as a whole adopted it; about fifteen years for the diesel locomotive, twenty-five years for the Mikado locomotive, twenty years for the four-wheel trailing truck locomotive, twenty-five years for centralized traffic control, and thirty years for car retarders.[15] Inasmuch as the adoption rate depends in part on the profitability of inventions and the size of the investment required, it is necessary to hold these factors constant when making comparisons with other industries. By making calculations on that basis, Mansfield found that the time between

Figure VIII
Output per Total Factor Input: Railroads, All Transportation, and National Economy, 1889-1970 (1929 = 100)



[a]Figures are given at only about ten-year intervals. The graph simply connects these points.

Sources: John Kendrick, Productivity Trends in the United States (NBER, 1961); and Kendrick and Grossman, Recent Trends and Cycles in Productivity of the United States Economy (unpublished).

10 and 90 percent adoption was about six years shorter in the steel industry, two years shorter in the coal industry, and fourteen years shorter in the brewing industry than in the railroad industry. To be sure, as Mansfield points out, the differences between the railroad and coal industries may not be statistically significant; but these can hardly be regarded as dynamic industries.[16]

Yet, even the railroads seem to be moderately responsive to increases in the degree of feedback. From 1950 to 1960, due mainly to competition from trucks, intercity freight traffic for railroads declined by about 25 percent. As a consequence, during the period 1960 to 1970 the average rate of increase of total factor productivity doubled that of the previous decade (see Figure VIII). About one-half of the gain came from closing down less profitable lines; and half from speeding up the rate of diffusion.

It can be seen, therefore, that, while we cannot make comparisons across industries, there are ways of detecting whether the industry in question is making good use of its potential. Moreover, when feedback within the industry in question begins to play a significantly more important role we can always be confident of the result.

III. UNDERSTANDING THE PRODUCTIVITY DECLINE

A number of reasons can be given for the U.S. decline in the rate of productivity gain since the mid-1960s, including the

impact of safety and environmental regulations, the rising cost of investment relative to depreciation allowances, and the increasing degree of constraint imposed on productivity gains by labor unions. Nevertheless, while these factors contributed to the severity of the decline, it is my conviction that it would have occurred anyway. To be sure, one can imagine an economy which perpetually maintains its dynamism by adding one new industry during each time period. However, technological revolutions do come in bunches, with advances in one field (for example, semiconductors) paving the way for advances in another (for example, computers). And due to the order of magnitude increase in the cost of entry as a technology matures, sooner or later the rate of entry is bound to decline.

Moreover, this explanation not only holds true for the current predicament of the U.S. economy, but also for most of the long cycles (the so-called Kuznets cycles) in economic activity. Though the cycles begin with the generation of a wide diversity of ideas, during the prosperity period entry declines; and, as a consequence of the decline in entry, sooner or later the economy decends to a Hotelling equilibrium. For example, during the first part of this century the alternatives were certainly moving away from the center of a distribution in many industries. Yet, if we take Hotelling's word for it, by the late 1920s there were trivial differences in a variety of industries between products as well as between political parties.

It should be borne in mind, however, that one factor greatly contributed to the severity of the Great Depression that is not present today. The automobile boom resulted in an increase in output and investment not only in the automobile industry, but in a number of related industries -- increases that could not be sustained. However, today only a drastic decline in petroleum imports could have a similar impact on the economy.

Even longer economic cycles have been observed in other countries. Britain experienced a long cycle that began about 1800 and ended about 1880. As of, say, 1850 rivalry was widespread in British industry: witness the fact that prices of practically all industrial commodities rapidly fell. But by 1890, British industry as a whole had become famous for its slow history. And as rivalry died out there was a profound change in the internal characteristics of British firms; that is, whereas earlier British entrepreneurs came from a wide variety of backgrounds, by the end of the century British Captains of Industry were almost entirely lawyers and accountants. Indeed, it is for this reason, no doubt, that the British economy never fully recovered from the Great Depression of the 1880s. Since 1900 Britain has had the lowest productivity growth, a chronic balance of payments problem, and has experienced a very significant decline in living standards, as compared with other major industrial countries.

Recovery from a long cycle is by no means automatic. Indeed, it can be predicted that as an economy acquires a larger and larger proportion of older industries, in which firms do their

best to isolate themselves from feedback (whether by product differentiation, advertising, or protective tariffs), the average degree of openness in the economy as a whole will decline -- and, when it does, recovery from the long cycles will become progressively more difficult. To be sure, in many ways wars can alter this result. Consider, for example, the remarkable recoveries of the Japanese and German economies after World War II. However, no one would seriously propose that wars be provoked to accomplish what politicians are unwilling to do.

Long cycles in economic activities are dependent not only upon the entry of new firms. Large increases in the number of mergers are also indicators of an oncoming economic paralysis. For example, during the late nineteenth century there was an enormous increase in mergers in British industry. During the 1920s the United States experienced its second largest merger movement. And during the 1960s and 1970s a merger movement of similar proportions occurred, with the new factor being the emergence of international conglomerates.

From the point of view of the firm, mergers are easy to explain. Obviously, growth by acquisition is easier to attain than growth by entrepreneurship and luck. Moreover, to the extent that mergers result in diversification, they provide a way to insure firms against risks. However, what is good for an individual firm is not necessarily good for an entire economy. Almost inevitably mergers result in a decline in risk-taking, and, by so doing, contribute to a poor showing in productivity gains.

Vertical integration will almost inevitably result in a decline in risk-taking, because it leads to a decline in Types I and II uncertainties. Consider, for example, the British aircraft industry during the period 1950 to 1960. As of that time all aircraft companies except Rolls Royce were vertically integrated firms that developed and produced both aircraft and aircraft engines. Yet, the number of times a vertically integrated firm was able to mate one of its own engines to one of its own aircraft was less than the number that would be determined by chance.[17] The reason: in something like three out of four cases the airplane ended up with a Rolls Royce engine. Rolls Royce had an advantage because it enjoyed a relatively high degree of Type I uncertainty; that is, unless it developed superior engines it was in a relatively poor position to sell engines. So to deal with this uncertainty it had to put more emphasis on developing basic engine technology than did other companies. On the other hand, it enjoyed a greater degree of Type II uncertainty because, as far as the customers were concerned, it had more options. When one of its engines was successful, a vertically integrated aircraft company would rather switch to it than sell no airplanes. Consequently, with Rolls Royce in the picture they too had a greater incentive to take risks. A good example of an automobile firm that had a significant advantage, because it was less vertically integrated than its competitors, was Chrysler during the 1930s. According to William Abernathy, this provided the flexibility needed for Chrysler's pioneering of high-compression engines, streamlined cars, disk brakes, and power steering.[18]

Conversely, when all firms in an industry are vertically integrated, the degree of risk-taking will almost inevitably be smaller (because both buyers and sellers have to deal with a smaller degree of uncertainty). Indeed, the main reason for vertical integration is not the much advertised reason -- that it will result in a gain in static efficiency. Rather, vertical integration is to be regarded as a protective mechanism that minimizes the probability of creative destruction of physical capital and a highly interrelated administrative structure. In short, vertical integration protects the lazy monopolist from unpredictability.

Horizontal integration reduces risk-taking because it reduces Type I uncertainty. Consider a hypothetical example of a large electric sign company that purchases a highly successful small electric sign company that is still owned and managed by its founder. By becoming part of a larger firm the smaller one is obviously better insured against uncertainty. The former head of the small company may retire, or may develop a taste for fishing. But if he remains, his incentives will not be the same. Moreover, in the name of sound management practices, the parent company will almost always impose a variety of controls on the acquired company: controls that will maximize short-term profits at the expense of longer-run profits.

To be sure, mergers of smaller companies do not necessarily lead to this result. A small company is likely to be more aware than a large one of the cost involved in imposing many onerous constraints upon entrepreneurship.

It is often argued that without mergers the incentive to establish a new business would not be as great as it is today. However, a larger firm acquiring a smaller firm is not the only way of selling a business. Often a company is purchased by a group of individuals. To be sure, they may have difficulty in raising the capital; but it can hardly be argued that imperfections in the capital markets is a valid reason for mergers.

In brief, the principal economic argument against mergers is not that they lead to a greater concentration of economic power; but, rather, mergers have a negative incentive on risk-taking. And because they seriously jeopardize the preservation of an economy with a high degree of dynamic stability, mergers between large firms should have been outlawed many years ago.

Finally, there is another respect in which today's highly predictable new Victorian American state is like the older British Victorian state. Both Victorian periods reveal a marked decline in ability to successfully compete with other countries. As far as the United States is concerned, until about 1965 it traded with the rest of the world by exporting newly developed technologies and importing products made by technologies earlier developed here, as well as raw materials (the so-called Vernon trade cycle). However, it must be emphasized that the U.S. comparative advantage in specific products did not long remain the same; rather, it was a dynamic advantage. For example, during the 1880s, when rivalry was still thriving in the steel industry, the United States exported steel to Britain and Scotland -- and, just as we are now accusing the Japanese of dumping, the British

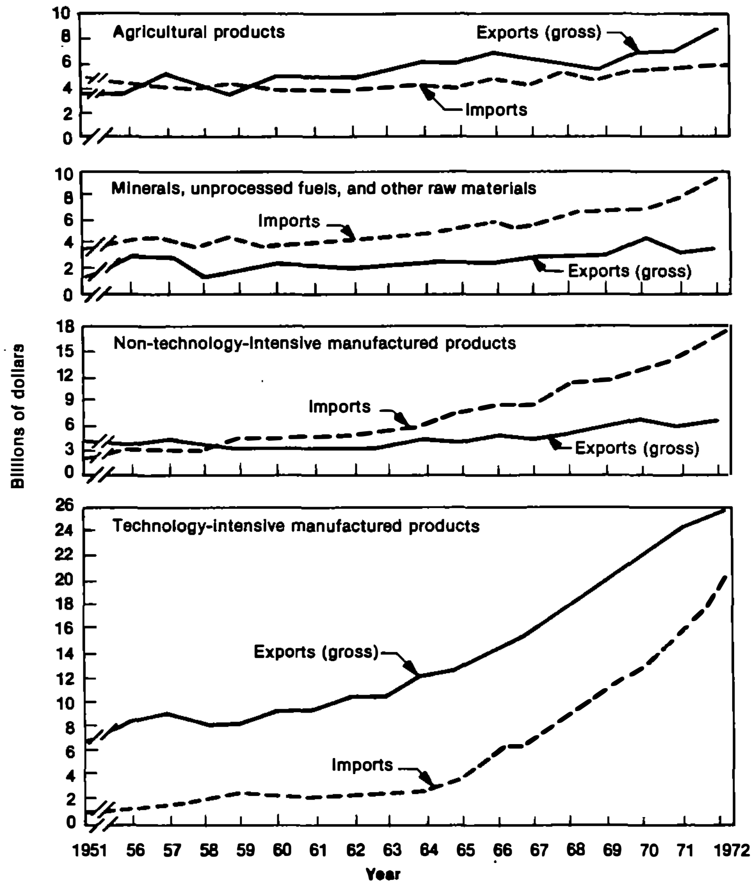
were then accusing us. Later our comparative advantage shifted to automobiles and automobile machinery; and still later to commercial aircraft, synthetic fibers, computers, and semiconductors. As far as the newer technologies are concerned, the U.S. advantage resulted from the relative ease of starting new firms. On the other hand, the primary reason the United States had a disadvantage with respect to the export of older technologies is that, generally speaking, the foreign firms were newer and more energetic.

However, as Figure IX shows, since the mid 1960s our ability to compete in foreign markets has steadily worsened Whereas we once enjoyed a virtual monopoly with respect to the export of the newer technologies, and imported only about one billion dollars annually, as of 1972 U.S. imports were running 20 billion dollars annually; and the gap between the import and export of the older technologies has steadily widened.

Although there can be no question that rivalry in the U.S. economy has declined, unfortunately it is not possible to measure it. Only for a relatively few industries do we have data on changes in market shares. The Census Bureau does have the needed information. But, inasmuch as it cannot release information on individual establishments to the general public, the Census Bureau will have to be persuaded to make the required calculations! Nevertheless, there is much indirect information available -- information on the internal characteristics of firms -- suggesting that the degree of rivalry is not what it was. For example, in the 1979 Battelle Report, "Probable Levels of R&D Expenditures in 1979," among the internal barriers to

FIGURE IX

UNITED STATES TRADE 1951-1972



Source: Michael Boretsky, U.S. Technology: Trends and Policy Issues (Washington, D.C.: United States Department of Commerce, 1973), p. 37.

innovation are listed the following:

1. A growing insistence on certainty of profits in the short term.
2. The "not invented here" syndrome.
3. Growth of a professional management class which has no entrepreneurial stake in the business.
4. Formalization of short-term executive tours of service -- e.g., up, down, sideways, or out every three to five years -- discouraging longer-term, innovative projects.
5. Use of executive incentives programs which emphasize accounting concepts of achievement.
6. Failure to organize for innovation -- instead, business is increasingly organized for steady profitability and not for risk-taking.
7. Tendency to try to buy corporate growth through acquisitions rather than through innovation and/or expansion.[19]

Finally, dynamic theory contributes not only to our understanding of the productivity slowdown, but also to the relationship between demand-pull (buyers) inflation and cost-push (sellers) inflation. Typically these are discussed as if they were entirely different subjects. For example, the proponents of demand-pull inflation argue that the large public deficits associated with the war in Vietnam was the basic cause of the beginning of inflation in the United States. On the other hand, the proponents of cost-push inflation point to the fact that inflation began in the steel industry, when in that industry wages started to go up more rapidly than productivity gains -- wage increases that were closely followed by price increases. However, these are intimately related factors in the sense that with less rivalry in an economy, the more prone it is likely to be to inflationary shocks.

Rivalry actually performs two functions in an economy: (1) it acts as a stimulus to bringing about reductions in costs, and, hence, productivity gains; and (2) it acts as a deterrent on wage and price increases. The reason rivalry performs the second function is that when labor unions push for rapid increases in wages in an industry possessing a significant degree of rivalry, they will find that they have caused unemployment in the less profitable firms. Generally speaking, in all industries there are wide variations in profit rates -- with the consequence that the labor unions cannot afford to ignore the impact of their actions on the less profitable firms. This is not to say, of course, that the constraint on wages provided by rivalry is necessarily the same in all industries. In some industries labor union leaders do not seem to care about the impact of their actions on unemployment. Consider, for example, the musicians union. On the other hand, in many other industries labor union leaders seem to be quite sensitive with respect to the impact of their actions on unemployment. Therefore it seems reasonable to assume that the truth lies somewhere between these extremes.

On the other hand, in industries with little rivalry we can expect a relatively small degree of constraint on wage increases. For example, it is no accident that in the railroads it was the unions who benefited most from a system of economic regulation that had the effect of minimizing feedback in that industry. Nor is it an accident that prior to deregulation of

the airlines, when there was little rivalry in that industry, the really gigantic gains in productivity were not reflected in lower rates. Thus, whereas during the period 1955-1965 total factor productivity increased by about 80 percent, average passenger rates did not decline -- they increased. Thus, it was not the consumer who benefited from productivity increases, it was the labor unions -- during the period in question there was no significant increase in airlines' profits.[20] Consequently, it can be said that this was an industry that featured cost-push inflation, even when there was relatively little inflation in the economy as a whole.

The relationship between demand-pull and cost-push inflation is simply this: even when there is a minimum degree of excess demand in the economy as a whole, we can expect some degree of cost-push inflation in those industries with the smallest degree of rivalry -- but with inflationary shocks highly localized. However, when the degree of excess demand increases, we can expect that those industries with the least amount of rivalry will be the first to take advantage of the situation by charging what the market will bear. However, when industries, such as the steel industry, act in this manner, the shocks from excess demand will become more general. In short, if my hypothesis is correct, in response to excess demand, inflation will gain momentum most rapidly in those industries with the least amount of rivalry, and cost-push inflation will be absent longest in those industries with the most rivalry.

As was indicated above, we do not have measures of rivalry for a wide number of industries, and, because we do not, there is no direct way to test this hypothesis. However, I do have unpublished Bureau of Labor Statistics data on productivity (P), wage changes (W) and price changes ($) for some 500 industries. It would have been preferable to have information on total factor productivity rather than labor productivity; but, for the purpose of testing a rivalry hypothesis the avoidable estimates on total factor productivity are far too aggregated.

To provide a rough test of the hypothesis, it will be assumed that a fair degree of correspondence exists between the rate of productivity increase in various industries and their degree of rivalry. Another reason this is a rough test is that the calculations ignore the fact that after the beginning of inflation in the 1960s the influence of rising input costs differed from industry to industry.

If my hypothesis is a reasonable one, we can expect to observe two relationships. First, there should be a negative correlation between the rate of productivity advance and the rate of price increase. As we already have seen, there is no automatic mechanism for distributing productivity gains in the form of lower prices. Therefore, if rivalry is generating relatively large productivity increases, it should also generate relatively small price increases. Second, in the high productivity industries the relationship between wage increases and productivity advances should be more constrained than in the low productivity industries. If rivalry is doing a good job in generating productivity advances, then it should be doing so in constraining

wage increases.

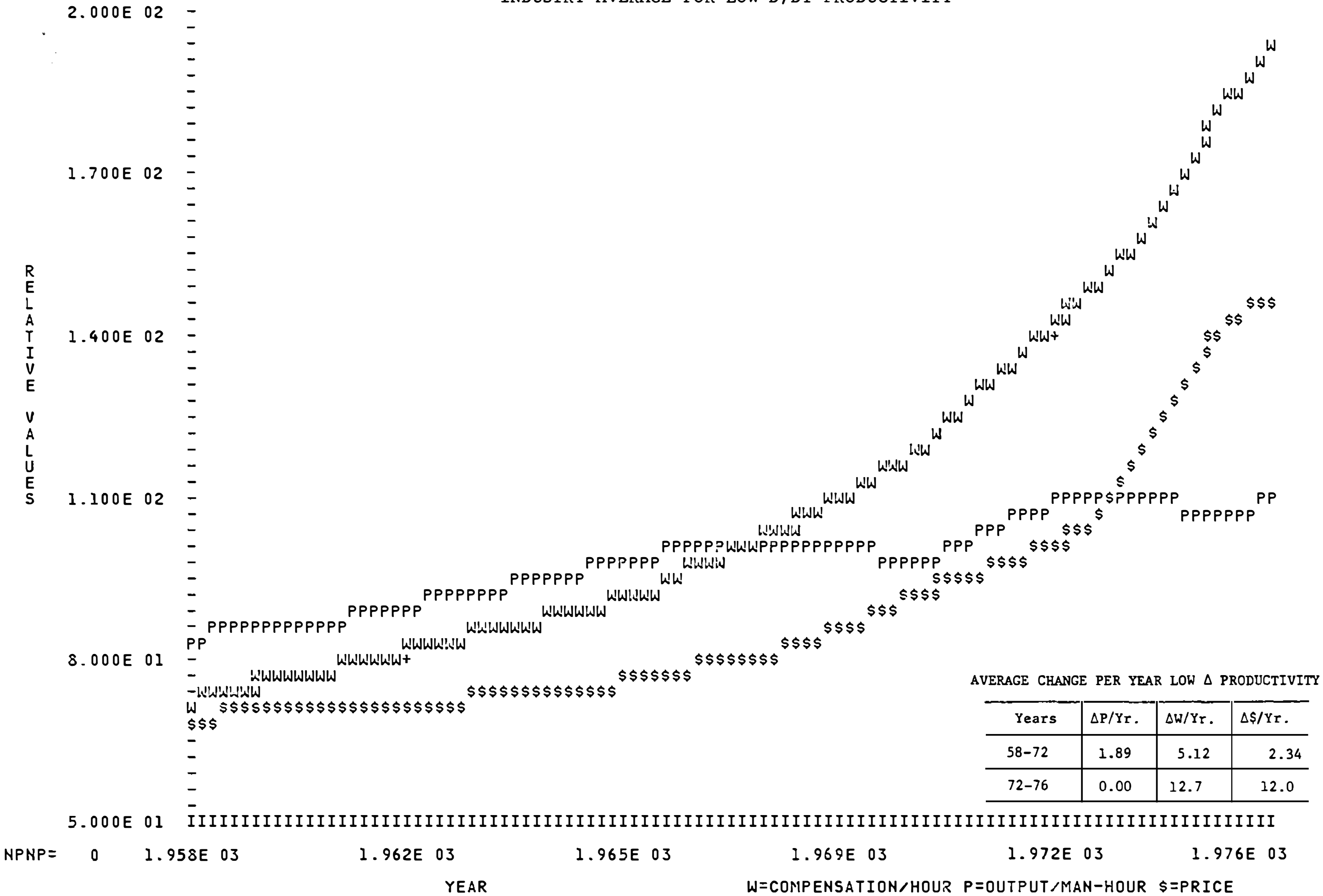
The computations contained in Figures X, XI and XII were made by dividing the 500 industries into three groups ranked in terms of productivity performance: low, medium and high. As the chart indicates, during the period 1965 to 1972 there was a strong negative correlation between productivity and price changes; and relative to the difference in the average annual rate of productivity gains, wages in the high productivity industries increased only about one-half as much as those in the low productivity industries. Thus, while expectations play an important role in wage changes, they are not based on the consumer price index but, rather, on the previous degree of rivalry in the industry concerned. In other words, a low degree of rivalry and a high degree of unstatesmanlike behavior on the part of labor union leaders go hand in hand.

As might be expected, there is a good deal of scatter around the average relationships just discussed. However, as Figures XIII and XIV indicate, the relationships are nonetheless quite impressive. The most important industries in each group and their performance are shown in the Appendix Tables. Among the poorest performers measured in price terms were various machine and machine tool industries, blast furnases and steel mills, printing and publishing, and newspapers.

On the other hand, it is also apparent that in the period 1972-1976 the differences in price and wage behavior between the three groups became insignificant, and, with wages and prices in all of them increasing at exponential rates. When

FIGURE X

INDUSTRY AVERAGE FOR LOW D/DT PRODUCTIVITY



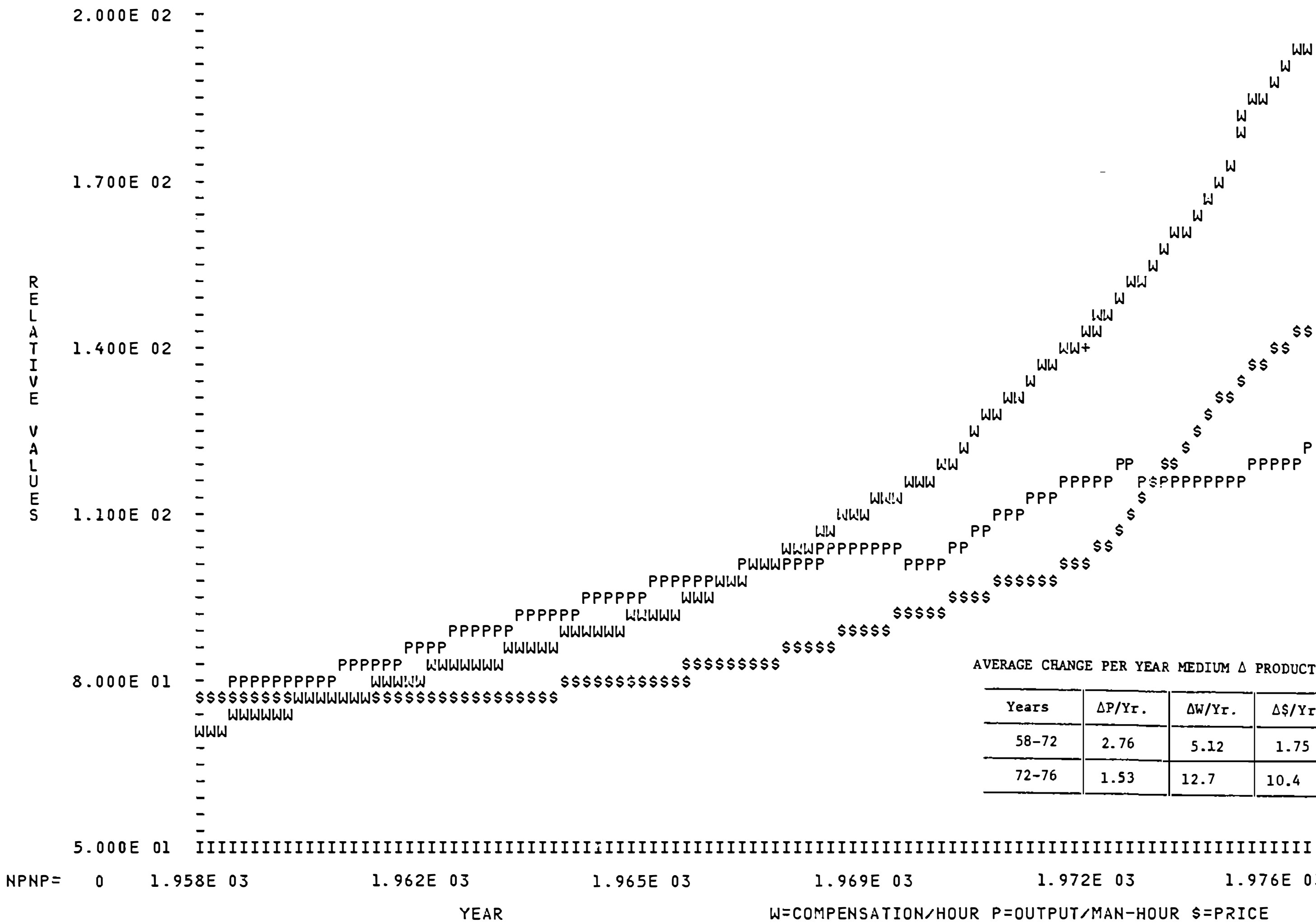
AVERAGE CHANGE PER YEAR LOW Δ PRODUCTIVITY

Years	ΔP/Yr.	ΔW/Yr.	Δ$/Yr.
58-72	1.89	5.12	2.34
72-76	0.00	12.7	12.0

Source: Bureau of Labor Statistics.

FIGURE XI

INDUSTRY AVERAGE FOR MEDIUM D/DT PRODUCTIVITY



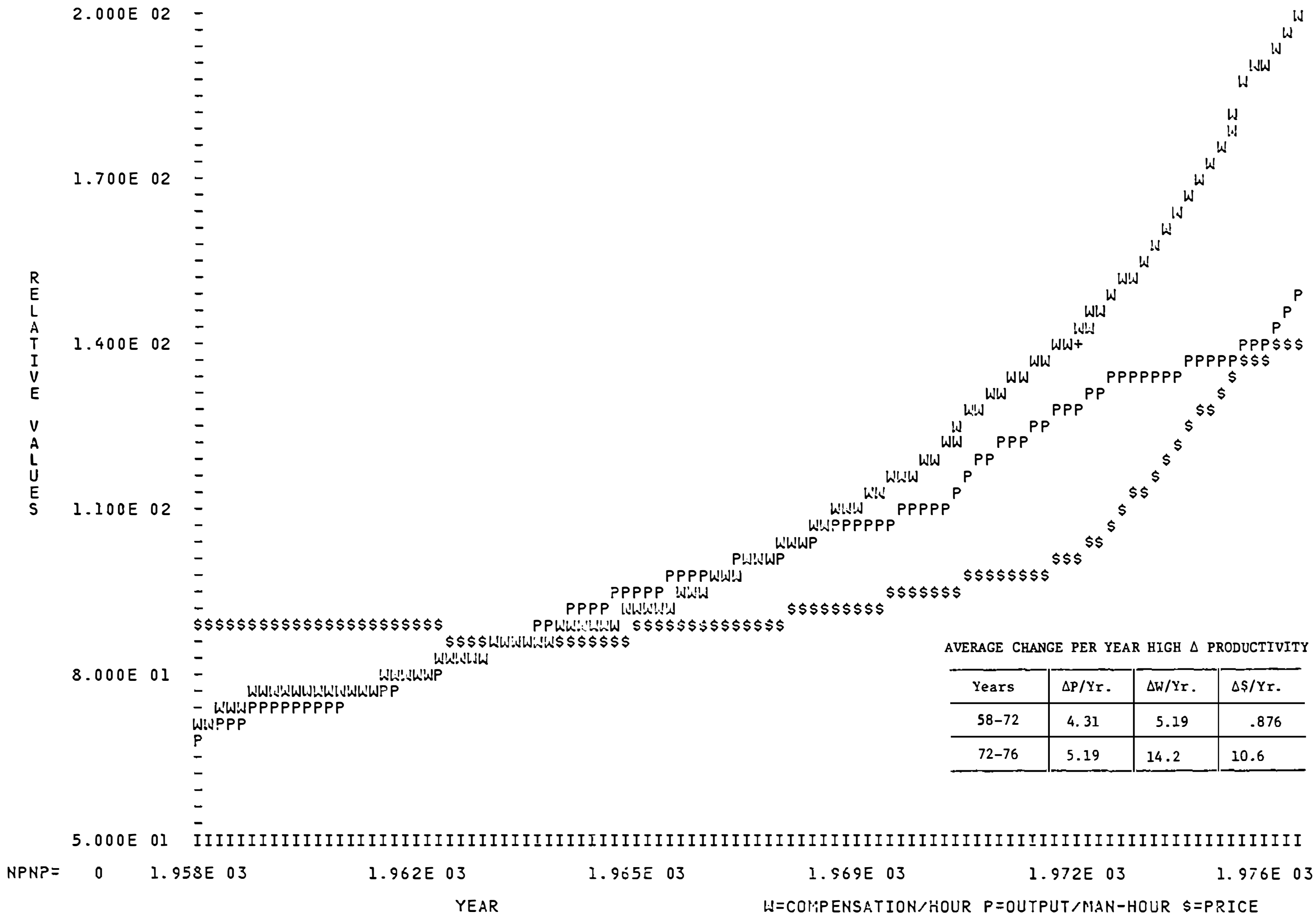
AVERAGE CHANGE PER YEAR MEDIUM Δ PRODUCTIVITY

Years	ΔP/Yr.	ΔW/Yr.	Δ$/Yr.
58-72	2.76	5.12	1.75
72-76	1.53	12.7	10.4

Source: Bureau of Labor Statistics.

FIGURE XII

INDUSTRY AVERAGE FOR HIGH D/DT PRODUCTIVITY



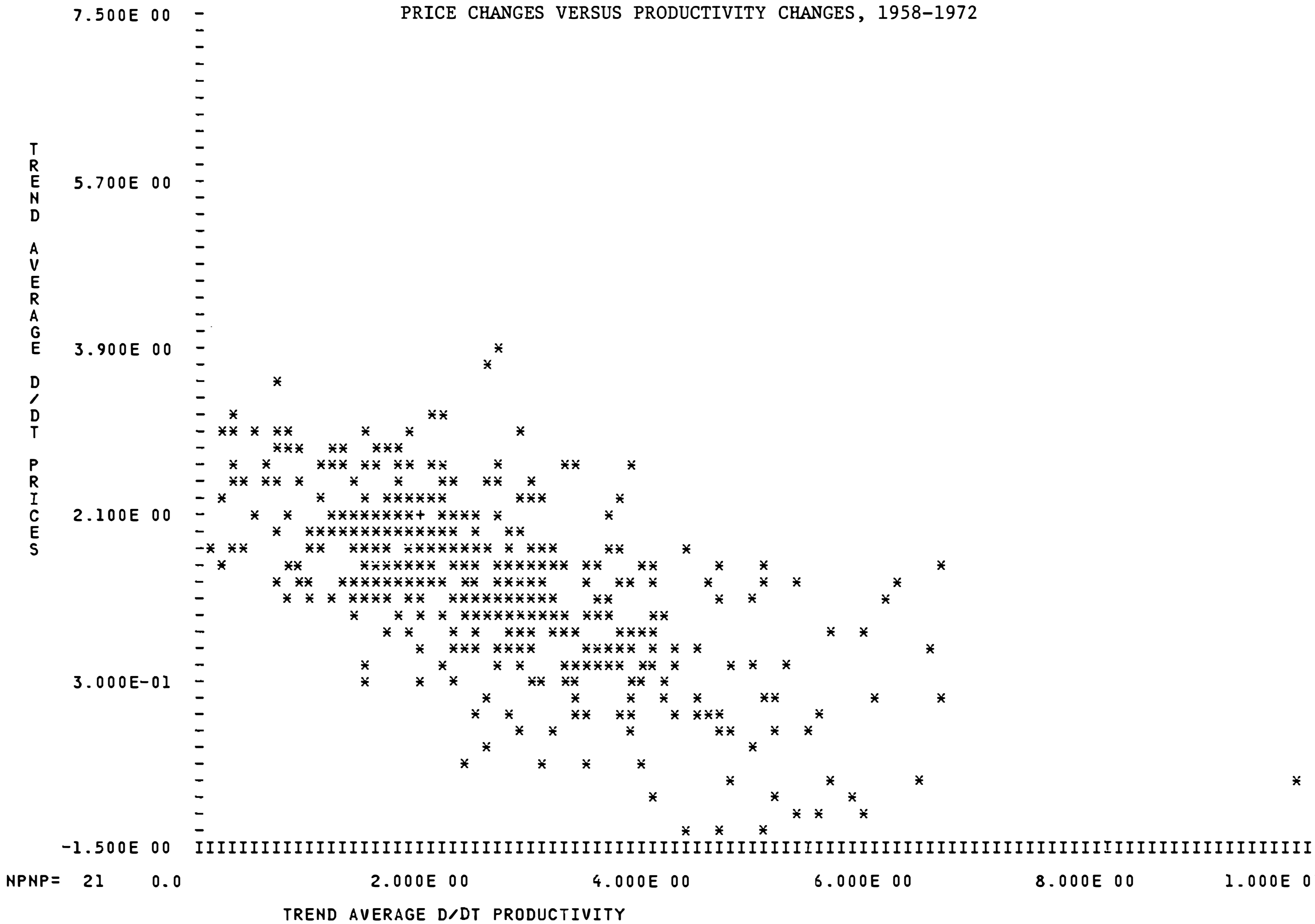
AVERAGE CHANGE PER YEAR HIGH Δ PRODUCTIVITY

Years	ΔP/Yr.	ΔW/Yr.	Δ$/Yr.
58-72	4.31	5.19	.876
72-76	5.19	14.2	10.6

Source: Bureau of Labor Statistics.

FIGURE XIII

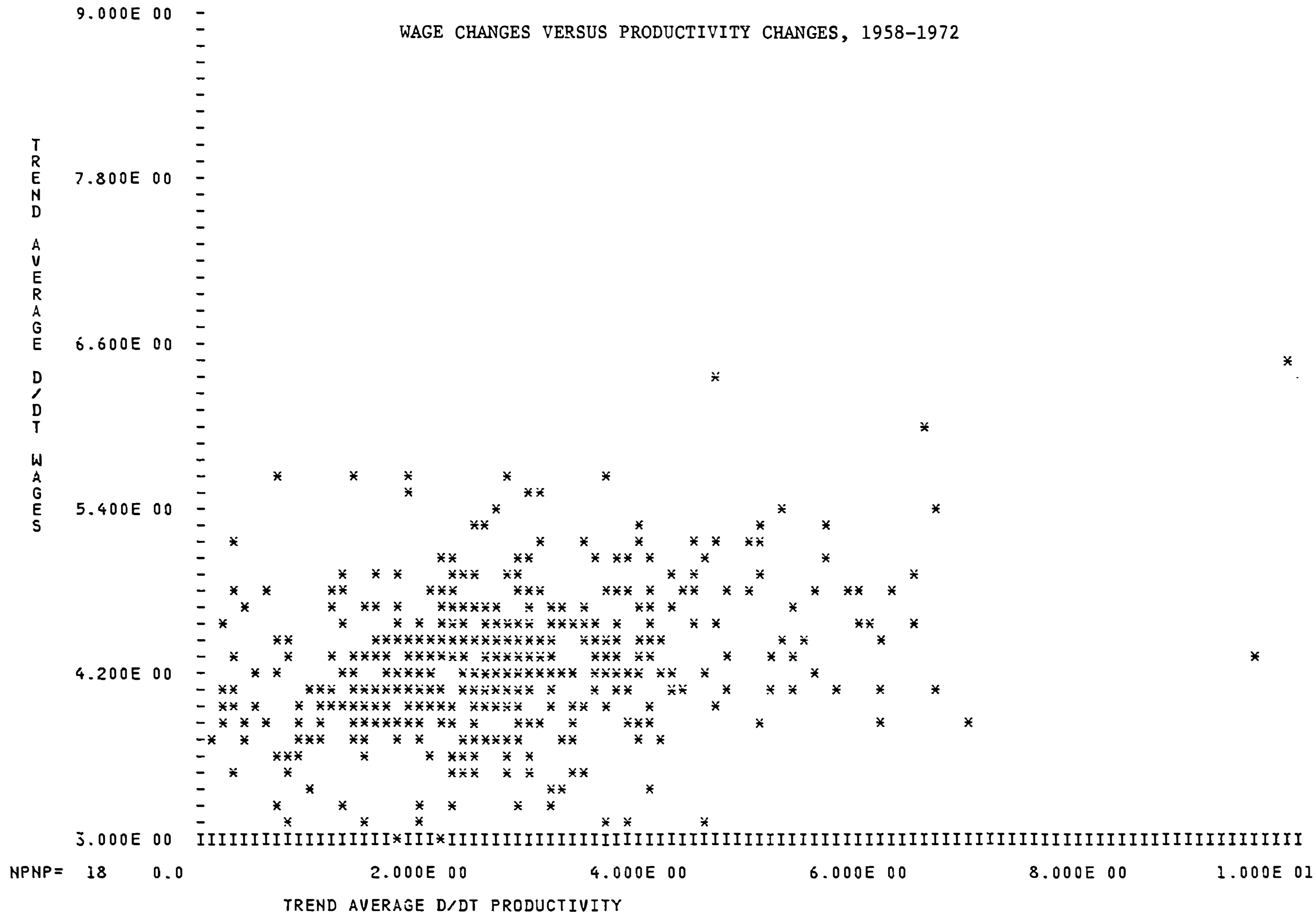
PRICE CHANGES VERSUS PRODUCTIVITY CHANGES, 1958-1972



Source: Bureau of Labor Statistics.

FIGURE XIV

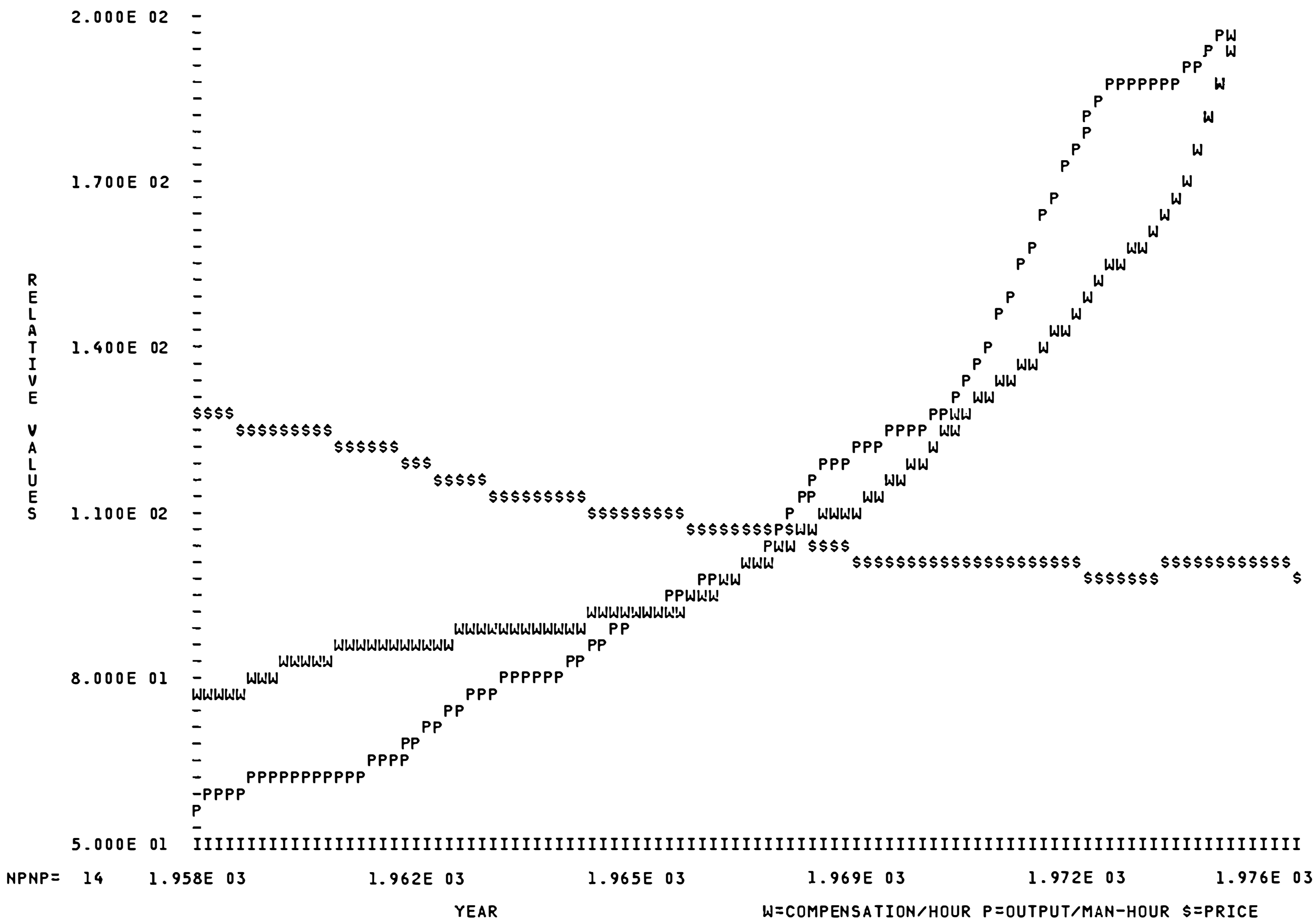
WAGE CHANGES VERSUS PRODUCTIVITY CHANGES, 1958-1972



Source: Bureau of Labor Statistics.

FIGURE XV

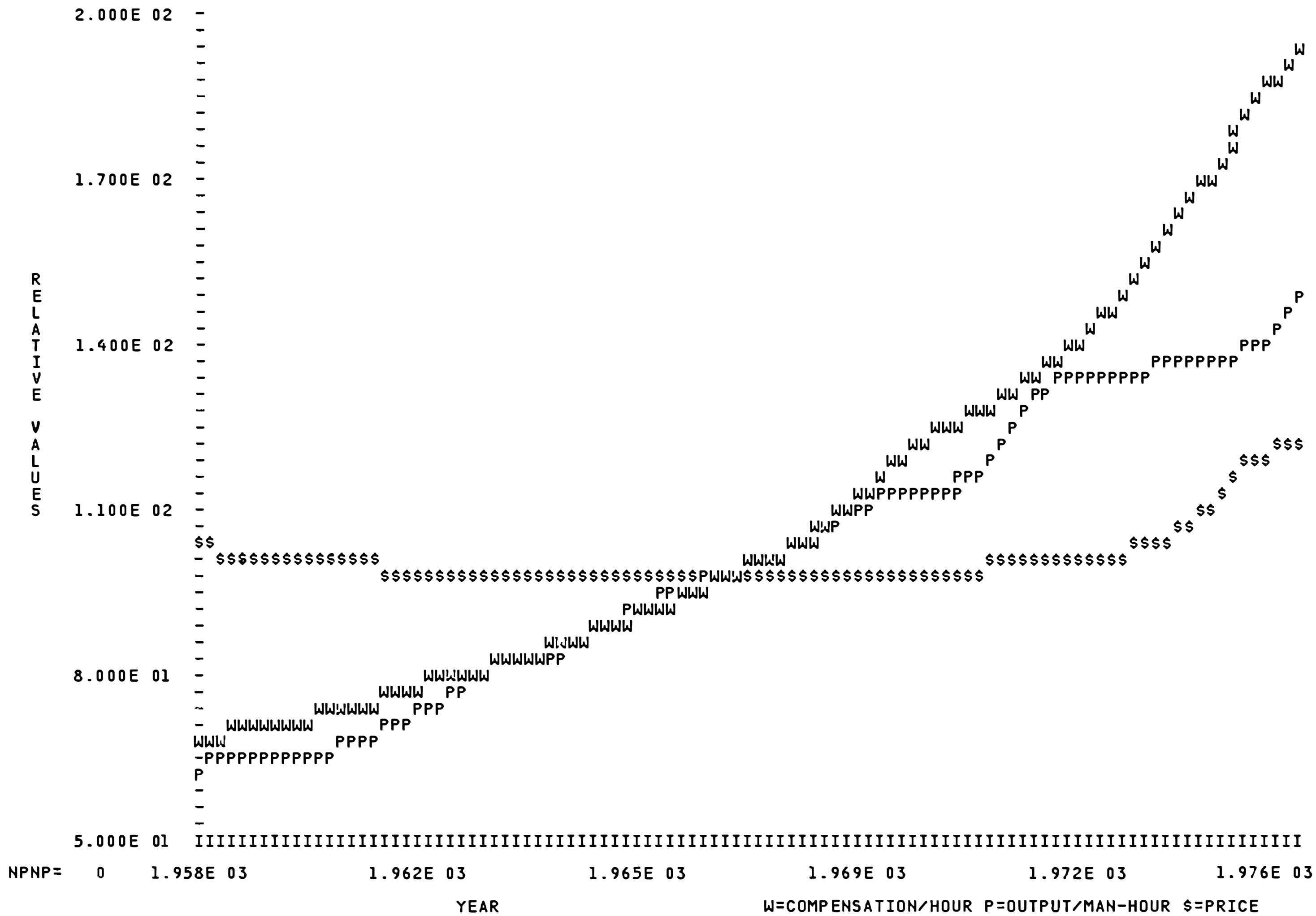
RADIO AND TV RECEIVING SETS
June 20, 1978



Source: Bureau of Labor Statistics.

FIGURE XVI

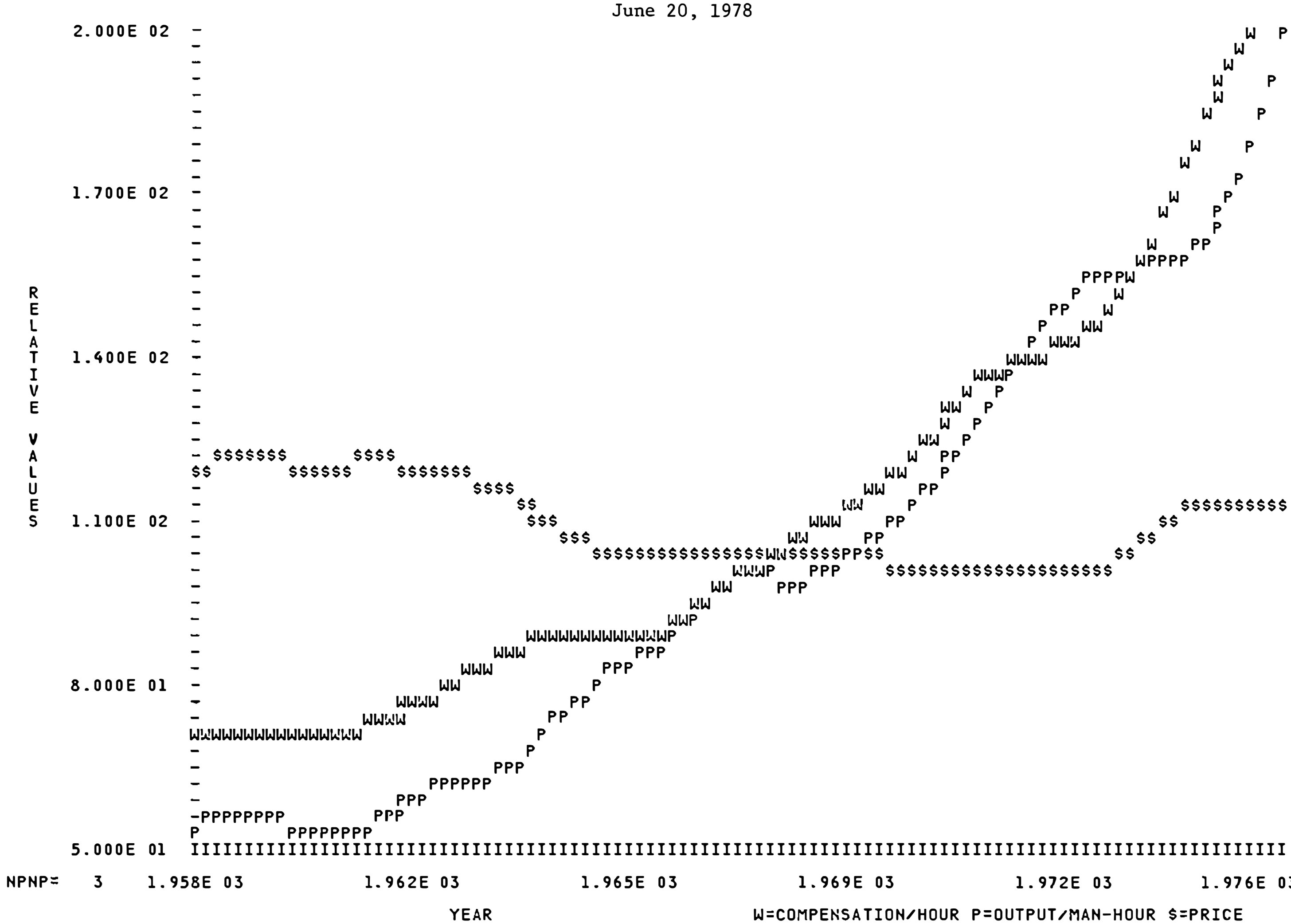
PHARMACEUTICAL PREPARATIONS
June 20, 1978



Source: Bureau of Labor Statistics.

FIGURE XVII

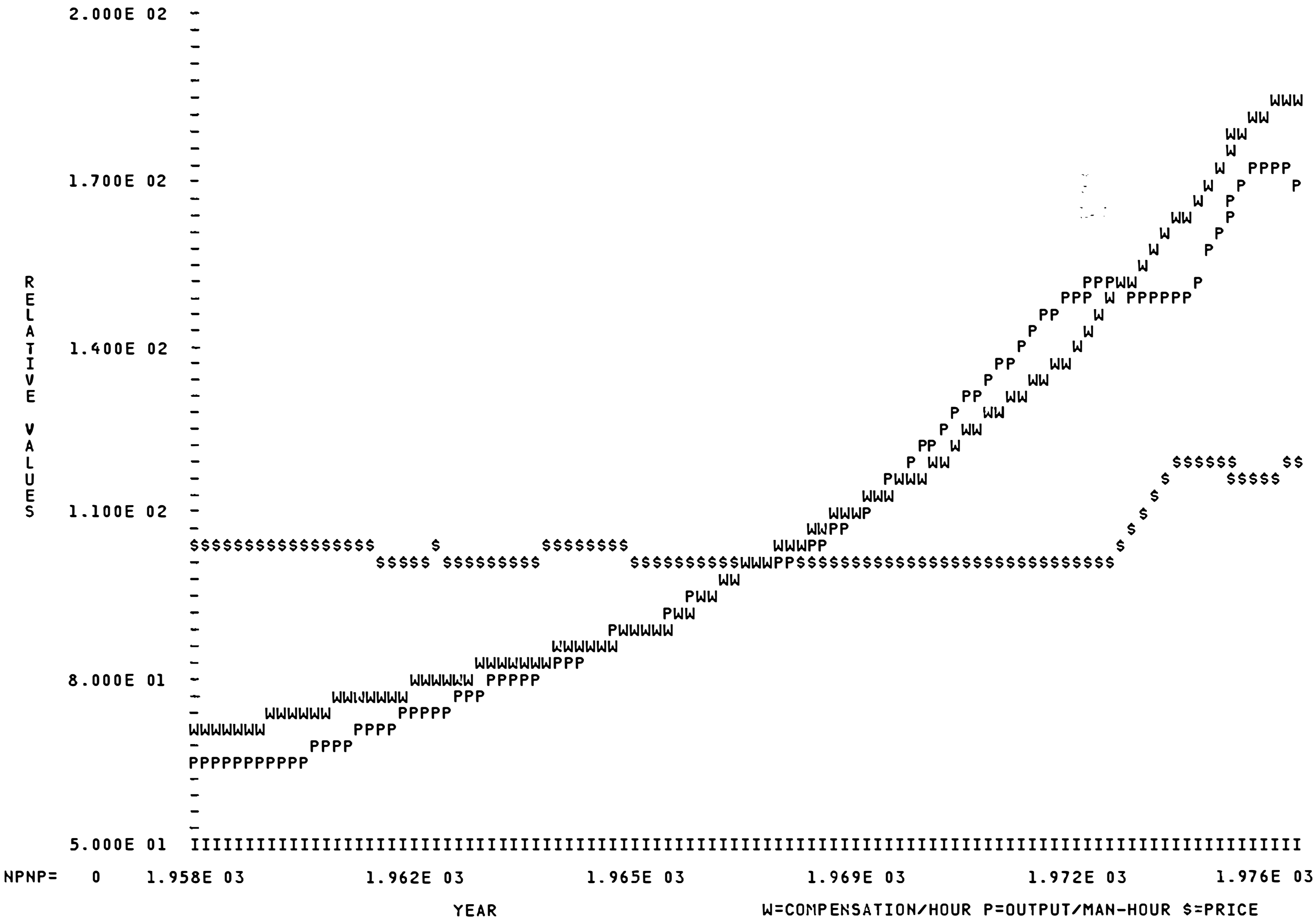
SEMICONDUCTORS AND ELECTRONIC COMPONENTS
June 20, 1978



Source: Bureau of Labor Statistics.

FIGURE XVIII

KNITTING MILLS
June 20, 1978



Source: Bureau of Labor Statistics.

it comes to overcoming the inhibitions of business and labor union leaders to engage in anticompetitive behavior, there apparently is nothing like inflation.

Needless to say, a great deal of work remains to be done before we have a satisfactory explanation of modern inflation. However, one thing is crystal clear: while a policy of fiscal restraint will certainly help to mitigate inflation, it cannot restore economic stability. Quite as important is the necessity to promote competition.

An even more fundamental result of a decline in rivalry is that it results in an economy in which a particular employment rate is associated with a higher inflation rate. (Technically speaking, a decline in rivalry results in an upward shifting of the Phillips curve.) To be sure, an economy with a high degree of rivalry will feature a good deal of short-term frictional unemployment, due to the fact that when some firms are experiencing "prosperity" others will be featuring "recession." Almost invariably, however, industries with a high degree of frictional unemployment will exhibit a rapid increase in total employment. Consider, for example, the automobile industry during the 1900s, the commercial aircraft industry during the 1930s, and the synthetic fibers industry after World War II. On the other hand, when there is so little rivalry in an industry it cannot compete with foreign firms or with other industries producing substitute products, employment opportunities are increased in other countries at the expense of an increasing degree of long-term unemployment in the country concerned. Consider, for example, the chronic

unemployment problems in the Scottish steel and textile industries; or consider the fact that with 20 percent of U.S. steel supplies now being imported from Japan, Youngstown and Pittsburgh are now facing chronic unemployment problems.

Officials from the steel industry put the blame for low capacity utilization on the inability of steel companies to raise the capital to modernize their facilities. But at the same time as their ability to compete in foreign markets was steadily erroding, U.S. steel firms were expanding into such fields as cement, railroads, ocean transport, seabed minerals, pipelines, oil-drilling equipment, titanium, and real estate! This example provides a vivid illustration of the price the United States is paying for not having outlawed mergers years ago. Many of our political leaders do not seem to understand that competition not only stimulates productivity gains, it is an important instrument in preserving an economy that does not require a huge amount of unemployment in order to restrain inflation.

However, the most impressive evidence of what is in store for the United States, if better ways to promote competition cannot be found, is the relationship between unemployment and price changes during the 1975 downturn. At that time, industrial prices continued to rise although the unemployment rate rose to almost 8 percent of the total labor force. Moreover, long-term unemployment (unemployment of 15 weeks and over) rose from 16 percent of total unemployment in 1970 to 32 percent in 1975, and declined only to 29 percent in 1977.[21]

Actually, this experience is reminiscent of the Great

Depression, when the prices of many industrial commodities proved to be irresponsive to increases in the degree of uncertainty. To be sure, economists were unable to explain such stickiness as a function of concentration ratios. However, a high correlation between concentration ratios and a high degree of feedback (as measured by changes in market shares) is not to be expected. Thus, whereas the aircraft and steel industries were both highly concentrated industries, progress in reducing costs was more rapid in the first case than in the second.

In conclusion: although this started as a project aimed at explaining the slowdown in productivity gains, it should be apparent that this subject simply cannot be studied in isolation of what is happening in the economy as a whole. Thus, though the hidden foot is the major factor in explaining the rate of productivity gains, it performs other important functions as well. Indeed, if a dynamic economy is defined as an economy which, by virtue of having an effective hidden foot, can rapidly move alternatives away from the center of a distribution, then it should be apparent that the major advantage of dynamic capitalism over socialism is that dynamic capitalism has a superior ability to make economic progress. On the other hand, a static capitalist economy that can generate only trivial differences between alternatives has no important advantage over socialism; and to his great credit, Harold Hotelling was the first economist to recognize this fact of life.

Nevertheless, it is ironic that those people who go the furthest to extol the virtues of dynamic capitalism are,

generally speaking, the people least willing to improve the effectiveness of competition.

IV. RESTORING A DYNAMIC ECONOMY

It should be apparent from the previous discussion there is simply no way to return to the golden age of 1955-1965 -- when President Kennedy complained that this country was not moving fast enough! But it also should be clear that the price of waiting to take effective measures to restore competition can be very high. Not only is the productivity performance of the United States' economy likely to worsen further, but we may witness sharper oscillations between inflation and recession.

My first two recommendations for providing the economy with a higher degree of dynamic stability are both concerned with lowering the barriers to entry in activities in which new firms are sorely needed. The third recommendation is concerned with changing the antitrust regulations in a manner to make life in the well-established firms somewhat more challenging.

1. The Need for New Firms in the Field of Automobile Engines

There can be no doubt that environmental regulations have greatly complicated the task of developing more efficient automobile engines by reducing fuel consumption. Developing automobile engines in terms of a double set of constraints is by no means an easy task. Nor can there be any doubt that a real need exists to move forward on both fronts simultaneously. Reducing environmental degradation is quite as important a way to improve productivity as is reducing gasoline consumption. Indeed, if the GNP were correctly measured, it would include the benefits from reducing environmental degradation.

On the other hand, it is also clear that the present form of environmental regulation has the effect of buying progress in the short-run by limiting the possibilities for more rapid progress in the longer-run. The essential reason that regulation has this effect is that it supplies perverse incentives for the generation of a diversity of alternatives. Firms are motivated to concentrate on the same technical approach, because so doing provides the best strategy for getting the regulations relaxed. Thus, it is no accident that one of the best internal combustion engines available today, not only in terms of its being a relatively clean engine that boasts somewhat high gasoline mileage and easy maintenance, is that developed by Honda. Curiously enough, our regulations supply better incentives to foreign car manufacturers than to American car manufacturers.

What might be done to remove the disadvantage of the American automobile manufacturers? R&D contracts should be used as a means of establishing new firms to work on promising technological possibilities. There is certainly a precedent for such action -- during the 1920s military R&D contracts were used as a means for establishing firms to develop new types of aircraft engines. And, if it were politically possible to take such action when Calvin Coolidge and Herbert Hoover were running this country, why is it not possible today?

This is not to say, however, that automobile firms

should be discouraged from working on new types of engines. Quite obviously, the more competition, the greater the probability of making more rapid progress. To be sure, if, as officials from the automobile companies argue, the industry is already operating at its peak dynamic capacity, no additional challenge is required. But in this case the automobile industry should be just as thankful for technology developed on the outside as are computer companies. On the other hand, if the people in charge of engine development in the automobile industry are correct in asserting that they could make more rapid progress were it not for the constraints imposed on them by top management, then new entrants will make it easier for them to argue with their bosses. In either event, government actions to help establish new firms will make the automobile industry better off than it is today

2. Decoupling the Generation of Electricity from Other Activities of Public Utility Companies

This proposal would, on the one hand, involve separation of generating electricity from the activities of transmitting and distributing electricity and, on the other, encouraging independent firms to compete in the generation of electricity on the basis of cost. To be sure, there are some outlying areas in which such competition would be precluded. But generally speaking, the necessity of preserving scale economies cannot be given as a reason for not having such competition. In fact, public ulilities commonly buy electricity from each other.

The importance of such a decoupling stems from two factors. The first is that the incentives provided for searching for low-cost alternatives are probably weaker than in any other industry in the entire economy. Not only is there little or no price rivalry between utility companies, but in normal times public utility rate-making procedures provide more or less the same incentives as cost-plus contracts. True, in times of inflation regulatory commissions are loath to pass on cost increases. However, in neither event can it be said that public utility commissions provide the same kind of feedback as would be provided by having independent companies compete on the basis of cost. If the United States and other countries had developed automobiles in the same manner that they are undertaking the development of nuclear energy, the industry never would have evolved beyond steam cars costing about 25,000 dollars (in today's prices). In terms of today's perspective that, of course, might have been a fortunate outcome. However, the example bears out a somewhat less obvious point, to wit: if regulation ever does work, it will because of luck and luck alone.

The second reason for the proposed decoupling is that when it comes to the development of exotic new technologies the public utilities are no more capable than the railroads would have been to develop airplanes.

As a consequence of poor incentives and an almost zero ability on the part of public utilities to engage in dynamic behavior, the country has had to pay an exorbitant price for the development of nuclear energy, both in terms of cost and safety. To be sure, public utility companies cannot be blamed for all that has happened. They did not develop either the design

concepts or the detailed designs for the power plants. Nor did they establish the safety regulations. However, the diffusion of responsibility is in part a reflection of the fact that the utility companies do not possess the required competence to play a significant role in the generation of new alternatives.

Consider the very different situation in the field of commercial aircraft development. Just as safety requirements are imposed on nuclear power plants by a public agency, so are safety requirements imposed on commercial aircraft by a public agency. Moreover, the aircraft companies have no less of a stake in the safety of airliners than utility companies have had in the safety of power plants. Yet, the aircraft companies themselves have played an important role in the development of safe aircraft. For example, when the British Comet airplane developed serious problems, Boeing sent a team to Britain to help overcome these problems. Is it conceivable that nuclear power companies will ever develop the same competence to deal with their power plant safety problems?

Or to provide another example, when chemical companies build new plants, they too have them built by architectural-engineering companies. Unlike nuclear power companies, chemical companies take complete responsibility for providing the design concepts. Moreover, when built, such plants are operated by handpicked crews who, in turn, provide valuable feedback for the design of other new plants. But, again, is it conceivable that utility companies will ever acquire the competence to engage in such behavior?

This is not to suggest, however, that the United States government ought to build more nuclear plants. My point is a general one: all new plants for generating electricity should be operated by independent companies. With respect to conventional power plants, utility companies' incentives for discovering clever ways to cut costs always have been and still are very poor. The principal difference between the past and the present is that it is now more important to provide better incentives. Given this country's predicament in generating an adequate rate of productivity gain, we no longer can afford the luxury of making power costs even 15 to 20 percent higher than they need be. On the other hand, when in the next decade or two it becomes possible to deliver solar energy into a central grid, its economical development will also be seriously jeopardized if trusted to the same kinds of incentives and an almost complete inability to deal with new circumstances.

3. Putting a Hidden Foot into the Antitrust Laws

If this country is ever to escape from stagflation, entrepreneurs represent an indispensable asset. But, while the United States possesses quite as many entrepreneurs as it ever did, this scarce resource is being squandered because its economy as a whole is becoming ensconced in a Hotelling equilibrium. There are, of course, a few industries in which the hidden foot continues to play an effective role. However, to the extent the hidden foot function is being performed, it is performed mainly by foreign

firms.

Moreover, it should be apparent from the previous discussion that the maintenance of a Hotelling equilibrium requires no overt collusion. As we have seen, when business executives get to know each other very well, because the actions in which they engage are highly predictable, there is no necessity for them to collude in order to preserve the equilibrium. To be sure, in Adam Smith's world entrepreneurs in a particular trade were constantly fraternizing to conspire against the public at large. However, that was long before the game of product differentiation had been discovered. Also keep in mind that this game is played so many times over that entrepreneurs have the opportunity to learn from their experiences. Consequently, the kind of behavior envisioned in the prisoner's dilemma response -- when a firm rushes to cut its prices to prevent its rival from striking first -- is ruled out, because if firms in an industry ever did engage in such behavior they would have learned their lesson.

The problem, therefore, is how to change the antitrust laws in a manner that will discourage behavior resulting in trivial differences in prices and products and encourage the generation of a wider diversity of ideas. In other words, the problem is how to create better incentives for dynamic behavior. As matters stand today, the incentives provided by the antitrust laws are better calculated to minimize risks in the legal profession than they are to encourage risk-taking in the business world. This occurs because lawyers feel more at home with legal conspiracy theory than they do with economic theory. Hence, they tend to specialize in cases for which they are best prepared. Consequently, when business firms ask their legal councils in which kind of behavior they can engage without risking an antitrust suit, the normal answer is: "Be a little different, but do not collude."

Providing better incentives for competitive behavior requires changing the antitrust laws in a manner so firms seeking advice on antitrust matters will be told the following: "We know that if you collude, you are in real danger. And we also know that the more your products and prices resemble those of your competitors, the greater is the danger of an antitrust suit. But we cannot tell you how far you can go to be just a little bit different. Just as Presidents have to operate within a broad band of uncertainty in predicting how far they can go before being accused of an impeachable offense, so will you have to operate within a broad band of uncertainty."

How might the Antitrust Division of the Justice Department (or its successor) operate to provide the required incentives? First, let us assume that if a concentrated industry as a whole fails to meet the test, its major firms will be broken up; and, further, the reorganized firms will be required to select their new top managements from outside the industry in question. In other words, let us assume that the reorganization not only results in less concentration of economic power, but that it also results in bringing fresh thinking into the industry

concerned. To be sure, the government has no right to tell firms what particular people should be selected for top management positions. But, inasmuch as a very narrow interpretation of self-interest can jeopardize the public interest, the government does have a right to insist that when an industry's dynamic performance is bad the firms look outside the industry for their new managements.

The principal criterion employed in bringing dissolution suits will be a dynamic one, that is, whether the alternatives continue to remain in the middle of a distribution or whether they are being pushed out at a significant rate. However, just how slowly alternatives need move from the center before an industry is in the danger zone, firms will not know. Just as automobile drivers do not know how far they can go in exceeding the speed limit, firms will not know at precisely what point they will enter the danger zone. In other words, the economists, engineers, and lawyers involved in bringing the cases will be given a certain amount of discretion on just where to draw the line.

It can be expected that when industries move into the danger zone changes in market shares will tend to become smaller and smaller; and the industry in question will experience greater and greater difficulties in meeting foreign competition. However, these are not infallable indicators. For example, quite significant changes in market shares can occur because of advertising, competition in style, or by some newly discovered means of competing in terms of fakery. The ability of American firms to meet foreign competition is not an infallible indicator, because many goods and services do not enter international competition. For example, housing does not -- and for that reason housing costs have risen enormously in nearly all countries.

It is because statistical tests of competition are not infallible that engineers will have to play an indispensable role in the new or renamed "Department to Promote Competition." Quite obviously, neither economists nor lawyers possess the competence to distinguish between a minor and a significant change in an alternative, particularly when the change involves an improvement in quality. Competition in terms of price is, of course, relatively easy to measure.

Finally, from the point of view of fairness, the enabling legislation should contain two provisions. In the first place, in order to provide firms with the opportunity to adjust to the new law to promote competition (the new law to replace the Sherman Antitrust Act), a three year period will be allowed to elapse before any case is tried under the new Act. In the second place, because constraints on productivity gains imposed by labor unions can have more or less the same effect as a decline in rivalry (again, the field of housing provides a good illustration), the imposition of such constraints, when they cannot be justified for safety reasons, shall be regarded as reason for dissolution of the union and the selection of new labor union leaders. However, the government should not try to control wages, whether by wage-price guidelines or direct controls. Wages should be determined by the workings of the market. Under the new plan

to promote competition labor union leaders, too, will face real risks: if prices increase because of wage escalation they will risk unemployment; either that or major firms in the industry will risk dissolution.

The major purpose of this proposal is twofold: (1), to promote a higher rate of productivity growth by providing better incentives for risk-taking; and (2), to discourage wage increases from becoming more rapid than productivity gains by providing firms with better incentives than they have today for resisting wage increases. To be sure, this will increase the possibility of labor union strikes. But this is an almost inevitable price if the United States is to have more competition and a greater degree of price stability.

I recognize, of course, that at first glance this may seem to be a somewhat radical proposal. However, it really is not. In the first place, in the antitrust action against the tobacco industry, when it engaged in parallel actions with respect to products and prices during the 1930s, the major firms in the industry were found to be engaging in anti-competitive behavior even though there was no direct evidence of collusion. Apparently in the aftermath of the Great Depression lawyers were more willing to take risks. However, today the same type of industry behavior is no less excusable than it was during the Great Depression.

Secondly, I do not go nearly as far as Kaysen and Turner did in their pathbreaking book on antitrust by way of suggesting a wholesale breaking up of firms throughout American industry.[22]

I agree with their views with respect to the importance of limiting the concentration of economic and political power. And I am not concerned about possible losses in static efficiency, because they would be by far offset by gains in dynamic efficiency. However, I feel that under current conditions (as contrasted with the conditions in the 1950s as of the time they wrote their book) a very strong case can be made for undertaking dissolutions in a manner that will improve incentives for competitive behavior.

Competition and Democracy: Although generating a more rapid rate of productivity gain and restraining inflation are important objectives in themselves, there is an even more basic reason for promoting a dynamic competitive society: it is an important adjunct for promoting Thomas Jefferson's concept of democracy. Although there is no generally agreed upon definition of Jeffersonian democracy, those who are familiar with his letters to Madison will agree that the following does not widely miss the mark: a democratic society is one that by virtue of generating a wide diversity of ideas can adapt itself to new circumstances. To be sure, I have been unable to find precisely such a statement in Jefferson's writings; but both his actions and his statements showed him to favor a society that could generate a wide diversity of ideas. Moreover, Jefferson certainly yearned for a society that could adapt to new circumstances: witness his plea for a small revolution every 20 years -- and what after all is the purpose of such a revolution than to put a hidden foot into

politics? Actually in their actions before the Revolutionary War, the British did put a hidden foot into politics; and the ideological revolution which preceded did generate a wide diversity of ideas. And if it did so, why not, then, have a small revolution every twenty years?

A dynamic competitive society complements Jefferson's concept of democracy, because highly interactive firms, in which people assume that they do not know all the answers, provide excellent training grounds for preserving a democratic society. Conversely, the highly authoritanian nature of cartelized firms in prewar Germany, primarily staffed with "yes-men," hardly provided an ideal training ground for the blossoming of democracy -- and the same was no doubt true in Japan before World War II. Moreover, both the Japanese and the Germans seem to be far more aware than we of the relationship between political democracy and democracy at the level of the firm.

Or to consider another example, Bruce Cain, a political scientist at Caltech, has been working on a study of electoral volatility in Britain.[23] He has found that the British political system has an amazing inability to deal with new circumstances. Entirely new issues such as devolution and immigration do arise. But the political candidates and the party bureaucracies remain almost as predictable as the planets. It is, of course, impossible to know which is the cause and which the effect: the economic system or the political system. The arrows of causation run both ways. Thus, highly bureaucratic labor organizations and business bureaucracies, or highly bureaucratic party organizations modeled in their image, provide the training ground for members of Parliament. And by thinking that one of these highly predictable bureaucratic bodies is the only way of life, members of Parliament mold the economy in the same image.

However, according to the writings of another Caltech political scientist, Morris Fiorina, American politics in its static orientation seems to be a full step ahead of British politics, because by dispensing favors to both individuals and interest groups Tammany Hall has in effect moved to Washington. Moreover, Fiorina has found that congressmen, in order to increase the effectiveness of their operations, have been building up the staffs of their home offices at a very impressive rate. Moreover, as he points out in some detail, by making entry more difficult these practices, in turn, have greatly contributed to a decline in political competition as measured by the longer and longer periods congressmen tend to remain in office.[24]

In short, a principal difference between the behavior of the congressional and business establishments at the present time and that of the 1920s, at which time Hotelling wrote his famous article, is that now both establishments go much further to immunize themselves from feedback by undertaking a high degree of "product differentiation."

The more basic reason for the similarity in behavior is that both are responding to short-run incentives. How might congressional incentives be changed? This can be accomplished

by limiting congressional tenure, as well as presidential tenure, to maximum periods of six years. This would change congressional incentives, because when in office politicians would think less about "what can I do to please this or that voter," and more about "how would I like to be remembered for what I did for my country?" Moreover, just as the business establishment could generate a wider diversity of ideas when the cost of entry is relatively low, so could the congressional establishment; in particular, with better incentives a wider diversity of people would run for office. In turn, a wider diversity of ideas would provide the country with a higher degree of congressional productivity. And a higher degree of congressional productivity would result in a higher degree of Jeffersonian democracy. Why should a country wait for twenty years to have a political revolution? Why not, instead, have a country that is more or less continuously able to adapt itself to new circumstances?

APPENDIX

FIGURE XIX

LOW D/DT PRODUCTIVITY INDUSTRY LISTING
(ORDERED BE EMPLOYMENT, GROUPED BY < D$/DT >)

1.	<DP/DT>= 1.7	<DW/DT>= 6.4	<D$/DT>= 3.8	3530 CONSTRUCTION AND RELATED MACHINERY	0	JUNE 20,1978
2.	<DP/DT>= 1.6	<DW/DT>= 5.7	<D$/DT>= 3.8	3550 SPECIAL INDUSTRY MACHINERY	0	JUNE 20,1978
3.	<DP/DT>= 1.8	<DW/DT>= 6.2	<D$/DT>= 3.8	2090 MISC. FOODS AND KINDRED PRODUCTS	0	JUNE 20,1978
4.	<DP/DT>= 0.1	<DW/DT>= 5.6	<D$/DT>= 4.7	3450 SCREW MACHINE PRODUCTS, BOLTS, ETC.	0	JUNE 20,1978
5.	<DP/DT>= 1.4	<DW/DT>= 5.6	<D$/DT>= 3.9	3441 FABRICATED STRUCTURAL METAL	0	JUNE 20,1978
6.	<DP/DT>= 0.2	<DW/DT>= 6.0	<D$/DT>= 3.9	2730 BOOKS	0	JUNE 20,1978
7.	<DP/DT>= 1.1	<DW/DT>= 5.4	<D$/DT>= 3.9	3494 VALVES AND PIPE FITTINGS	0	JUNE 20,1978
8.	<DP/DT>= 0.8	<DW/DT>= 5.7	<D$/DT>= 4.4	3360 NONFERROUS FOUNDRIES	0	JUNE 20,1978
9.	<DP/DT>= 1.6	<DW/DT>= 6.0	<D$/DT>= 4.2	2890 MISCELLANEOUS CHEMICAL PRODUCTS	0	JUNE 20,1978
10.	<DP/DT>= 1.1	<DW/DT>= 6.0	<D$/DT>= 4.2	3541 MACHINE TOOLS, METAL CUTTING TYPES	0	JUNE 20,1978
11.	<DP/DT>= 1.4	<DW/DT>= 5.7	<D$/DT>= 4.5	3559 SPECIAL INDUSTRY MACHINERY, NEC	0	JUNE 20,1978
12.	<DP/DT>= 0.1	<DW/DT>= 5.7	<D$/DT>= 4.7	3452 BOLTS, NUTS, RIVETS, AND WASHERS	0	JUNE 20,1978
13.	<DP/DT>= 0.2	<DW/DT>= 6.3	<D$/DT>= 4.0	2731 BOOK PUBLISHING	0	JUNE 20,1978
14.	<DP/DT>= 1.1	<DW/DT>= 5.7	<D$/DT>= 3.9	3566 POWER TRANSMISSION EQUIPMENT (3566,68)	0	JUNE 20,1978
15.	<DP/DT>= 1.7	<DW/DT>= 6.1	<D$/DT>= 4.7	3910 JEWELRY, SILVERWARE, AND PLATED WARE	0	JUNE 20,1978

1.	<DP/DT>= 1.8	<DW/DT>= 5.9	<D$/DT>= 3.5	3400 FABRICATED METAL PRODUCTS	0	JUNE 20,1978
2.	<DP/DT>= 1.6	<DW/DT>= 5.7	<D$/DT>= 3.4	2700 PRINTING AND PUBLISHING	0	JUNE 20,1978
3.	<DP/DT>= 1.7	<DW/DT>= 7.1	<D$/DT>= 3.6	3310 BLAST FURNACE AND BASIC STEEL PRODUCTS	0	JUNE 20,1978
4.	<DP/DT>= 1.7	<DW/DT>= 7.3	<D$/DT>= 3.7	3312 BLAST FURNACES AND STEEL MILLS	0	JUNE 20,1978
5.	<DP/DT>= 1.4	<DW/DT>= 5.8	<D$/DT>= 3.6	2710 NEWSPAPERS	0	JUNE 20,1978
6.	<DP/DT>= 1.4	<DW/DT>= 5.8	<D$/DT>= 3.6	2711 NEWSPAPERS	0	JUNE 20,1978
7.	<DP/DT>= 1.8	<DW/DT>= 5.2	<D$/DT>= 2.9	3100 LEATHER AND LEATHER PRODUCTS	0	JUNE 20,1978
8.	<DP/DT>= 1.6	<DW/DT>= 5.5	<D$/DT>= 3.5	3540 METALWORKING MACHINERY	0	JUNE 20,1978
9.	<DP/DT>= 1.3	<DW/DT>= 6.7	<D$/DT>= 3.7	3460 METAL FORGINGS AND STAMPINGS	0	JUNE 20,1978
10.	<DP/DT>= 1.3	<DW/DT>= 6.8	<D$/DT>= 3.6	3465 AUTO STAMPGS INCL CROWNS,CLOSURES,NEC (3465,66,69)	0	JUNE 20,1978
11.	<DP/DT>= 1.7	<DW/DT>= 5.1	<D$/DT>= 3.2	3140 FOOTWEAR, EXCEPT RUBBER	0	JUNE 20,1978
12.	<DP/DT>= 1.8	<DW/DT>= 5.2	<D$/DT>= 3.2	3144 FOOTWEAR, EXCEPT RUBBER AND SLIPPERS (3143,44,49)	0	JUNE 20,1978
13.	<DP/DT>= 0.9	<DW/DT>= 5.7	<D$/DT>= 3.7	3590 MISC. MACHINERY, EXCEPT ELECTRICAL	0	JUNE 20,1978
14.	<DP/DT>= 0.9	<DW/DT>= 5.7	<D$/DT>= 3.7	3599 MISC NONELEC MACH INCL CARBURETORS (3592,99)	0	JUNE 20,1978
15.	<DP/DT>= 1.7	<DW/DT>= 5.9	<D$/DT>= 2.9	3820 MEASURING AND CONTROLLING DEVICES	0	JUNE 20,1978

1.	<DP/DT>= 1.7	<DW/DT>= 5.0	<D$/DT>= 1.5	2341 WOMEN'S AND CHILDREN'S UNDERWEAR	0	JUNE 20,1978
2.	<DP/DT>= 1.1	<DW/DT>= 5.5	<D$/DT>= 1.5	2230 WEAVING AND FINISHING MILLS, WOOL	0	JUNE 20,1978
3.	<DP/DT>= 1.1	<DW/DT>= 5.5	<D$/DT>= 1.5	2231 WEAVING AND FINISHING MILLS, WOOL	0	JUNE 20,1978
4.	<DP/DT>= 1.7	<DW/DT>= 6.6	<D$/DT>= 0.9	2291 FELT GOODS, EXC. WOVENFELTS & HATS	0	JUNE 20,1978

Source: Bureau of Labor Statistics.

FIGURE XX

MEDIUM D/DT PRODUCTIVITY INDUSTRY LISTING
(ORDERED BY EMPLOYMENT, GROUPED BY < D$/DT >)

1.	<DP/DT>= 1.9	<DW/DT>= 6.8	<D$/DT>= 3.8	3300 PRIMARY METAL INDUSTRIES	0	JUNE 20,1978
2.	<DP/DT>= 3.1	<DW/DT>= 7.2	<D$/DT>= 4.0	2400 LUMBER AND WOOD PRODUCTS LESS 2431,34 PLUS 3792	0	JUNE 20,1978
3.	<DP/DT>= 2.3	<DW/DT>= 7.4	<D$/DT>= 4.5	2420 SAWMILLS AND PLANING MILLS	0	JUNE 20,1978
4.	<DP/DT>= 2.5	<DW/DT>= 7.7	<D$/DT>= 4.6	2421 SAWMILLS AND PLANING MILLS, GENERAL	0	JUNE 20,1978
5.	<DP/DT>= 2.6	<DW/DT>= 6.3	<D$/DT>= 3.8	3350 NONFERROUS ROLLING AND DRAWING	0	JUNE 20,1978
6.	<DP/DT>= 2.4	<DW/DT>= 7.4	<D$/DT>= 3.9	3321 GRAY IRON FOUNDRIES	0	JUNE 20,1978
7.	<DP/DT>= 2.1	<DW/DT>= 7.1	<D$/DT>= 4.1	3531 CONSTRUCTION MACHINERY	0	JUNE 20,1978
8.	<DP/DT>= 2.5	<DW/DT>= 6.4	<D$/DT>= 4.7	2060 SUGAR AND CONFECTIONERY PRODUCTS	0	JUNE 20,1978
9.	<DP/DT>= 2.4	<DW/DT>= 6.4	<D$/DT>= 3.8	2490 MISCELLANEOUS WOOD PRODUCTS PLUS 2448	0	JUNE 20,1978
10.	<DP/DT>= 2.0	<DW/DT>= 6.0	<D$/DT>= 3.9	3357 NONFERROUS WIRE DRAWING & INSULATING	0	JUNE 20,1978
11.	<DP/DT>= 2.0	<DW/DT>= 6.8	<D$/DT>= 3.8	3411 METAL CANS	0	JUNE 20,1978
12.	<DP/DT>= 1.9	<DW/DT>= 7.7	<D$/DT>= 4.5	3330 PRIMARY NONFERROUS METALS	0	JUNE 20,1978
13.	<DP/DT>= 2.2	<DW/DT>= 6.3	<D$/DT>= 3.9	2013 SAUSAGES AND OTHER PREPARED MEATS	0	JUNE 20,1978
14.	<DP/DT>= 2.0	<DW/DT>= 6.0	<D$/DT>= 4.7	3351 COPPER ROLLING AND DRAWING	0	JUNE 20,1978
15.	<DP/DT>= 2.3	<DW/DT>= 7.1	<D$/DT>= 4.9	2022 CHEESE, NATURAL AND PROCESSED	0	JUNE 20,1978

1.	<DP/DT>= 2.6	<DW/DT>= 5.9	<D$/DT>= 3.0	3500 MACHINERY, EXCEPT ELECTRICAL	0	JUNE 20,1978
2.	<DP/DT>= 2.4	<DW/DT>= 5.4	<D$/DT>= 2.2	2300 APPAREL AND OTHER TEXTILE PRODUCTS	0	JUNE 20,1978
3.	<DP/DT>= 2.7	<DW/DT>= 7.4	<D$/DT>= 2.3	3710 MOTOR VEHICLES AND EQUIPMENT	0	JUNE 20,1978
4.	<DP/DT>= 2.7	<DW/DT>= 7.5	<D$/DT>= 2.3	3711 MOTOR VEHICLES, CAR BODIES & PARTS (3711,14)	0	JUNE 20,1978
5.	<DP/DT>= 3.1	<DW/DT>= 6.8	<D$/DT>= 3.0	3720 AIRCRAFT AND PARTS PLUS 3764,3769	0	JUNE 20,1978
6.	<DP/DT>= 2.2	<DW/DT>= 6.4	<D$/DT>= 3.0	3200 STONE, CLAY; AND GLASS PRODUCTS	0	JUNE 20,1978
7.	<DP/DT>= 2.1	<DW/DT>= 5.7	<D$/DT>= 3.0	2500 FURNITURE AND FIXTURES PLUS 2431,34	0	JUNE 20,1978
8.	<DP/DT>= 3.0	<DW/DT>= 5.7	<D$/DT>= 1.9	3660 COMMUNICATION EQUIPMENT	0	JUNE 20,1978
9.	<DP/DT>= 3.1	<DW/DT>= 5.8	<D$/DT>= 2.5	3900 MISCELLANEOUS MANUFACTURING INDUSTRIES	0	JUNE 20,1978
10.	<DP/DT>= 2.4	<DW/DT>= 4.8	<D$/DT>= 1.9	2330 WOMENS AND MISSES OUTERWEAR	0	JUNE 20,1978
11.	<DP/DT>= 2.4	<DW/DT>= 5.6	<D$/DT>= 3.3	3440 FABRICATED STRUCTURAL METAL PRODUCTS	0	JUNE 20,1978
12.	<DP/DT>= 2.1	<DW/DT>= 5.8	<D$/DT>= 3.3	2750 COMMERCIAL PRINTING PLUS 2795	0	JUNE 20,1978
13.	<DP/DT>= 2.7	<DW/DT>= 5.7	<D$/DT>= 2.4	2320 MENS AND BOYS FURNISHINGS	0	JUNE 20,1978
14.	<DP/DT>= 2.1	<DW/DT>= 5.8	<D$/DT>= 3.3	2752 COML PRTG-LETTERPR,LITH,GRAV,LITHPLATE(2751,52,54,95)	0	JUNE 20,1978
15.	<DP/DT>= 2.6	<DW/DT>= 5.6	<D$/DT>= 3.5	2010 MEAT PRODUCTS	0	JUNE 20,1978

1.	<DP/DT>= 2.6	<DW/DT>= 5.4	<D$/DT>= 1.7	3662 RADIO AND TV COMMUNICATION EQUIPMENT	0	JUNE 20,1978
2.	<DP/DT>= 2.1	<DW/DT>= 4.7	<D$/DT>= 1.7	2335 WOMEN'S AND MISSES' DRESSES	0	JUNE 20,1978
3.	<DP/DT>= 2.4	<DW/DT>= 5.9	<D$/DT>= 1.2	2220 WEAVING MILLS. SYNTHETICS	0	JUNE 20,1978
4.	<DP/DT>= 2.4	<DW/DT>= 5.9	<D$/DT>= 1.2	2221 WEAVING MILLS, SYNTHETICS	0	JUNE 20,1978
5.	<DP/DT>= 2.9	<DW/DT>= 4.9	<D$/DT>= 1.1	3171 WOMEN'S HANDBAGS AND PURSES	0	JUNE 20,1978
6.	<DP/DT>= 3.0	<DW/DT>= 6.1	<D$/DT>= 0.7	2283 WOOL YARN MILLS	0	JUNE 20,1978
7.	<DP/DT>= 3.1	<DW/DT>= 6.7	<D$/DT>= 1.7	3275 GYPSUM PRODUCTS	0	JUNE 20,1978
8.	<DP/DT>= 2.8	<DW/DT>= 5.2	<D$/DT>= 0.8	2370 FUR GOODS	0	JUNE 20,1978
9.	<DP/DT>= 2.8	<DW/DT>= 5.2	<D$/DT>= 0.8	2371 FUR GOODS	0	JUNE 20,1978
10.	<DP/DT>= 2.8	<DW/DT>= 5.0	<D$/DT>= 1.7	3425 HAND SAWS AND SAW BLADES	0	JUNE 20,1978
11.	<DP/DT>= 2.0	<DW/DT>= 4.5	<D$/DT>= 0.8	3030 RECLAIMED RUBBER	0	JUNE 20,1978
12.	<DP/DT>= 2.0	<DW/DT>= 4.5	<D$/DT>= 0.8	3031 RECLAIMED RUBBER	0	JUNE 20,1978
13.	<DP/DT>= 3.1	<DW/DT>= 5.2	<D$/DT>= 1.5	2451 MOBILE HOMES,TRAILERS & CAMPERS(2451,3792) *Q	1	JUNE 20,1978

Source: Bureau of Labor Statistics.

FIGURE XXI

HIGH D/DT PRODUCTIVITY INDUSTRY LISTING
(ORDERED BE EMPLOYMENT, GROUPED BY < D$/DT >)

1.	<DP/DT>= 4.4	<DW/DT>= 6.3	<D$/DT>= 5.1	2900 PETROLEUM AND COAL PRODUCTS	0	JUNE 20,1978
2.	<DP/DT>= 5.0	<DW/DT>= 6.6	<D$/DT>= 4.0	2086 BOTTLED AND CANNED SOFT DRINKS	0	JUNE 20,1978
3.	<DP/DT>= 5.0	<DW/DT>= 6.6	<D$/DT>= 5.3	2911 PETROLEUM REFINING	0	JUNE 20,1978
4.	<DP/DT>= 5.0	<DW/DT>= 6.6	<D$/DT>= 5.3	2910 PETROLEUM REFINING	0	JUNE 20,1978
5.	<DP/DT>= 3.3	<DW/DT>= 9.3	<D$/DT>= 4.7	2410 LOGGING CAMPS & LOGGING CONTRACTORS	0	JUNE 20,1978
6.	<DP/DT>= 3.3	<DW/DT>= 9.3	<D$/DT>= 4.7	2411 LOGGING CAMPS & LOGGING CONTRACTORS	0	JUNE 20,1978
7.	<DP/DT>= 4.0	<DW/DT>= 6.5	<D$/DT>= 4.5	2070 FATS AND OILS	0	JUNE 20,1978
8.	<DP/DT>= 3.4	<DW/DT>= 7.2	<D$/DT>= 5.2	2610 PULP MILLS	0	JUNE 20,1978
9.	<DP/DT>= 3.4	<DW/DT>= 7.2	<D$/DT>= 5.2	2611 PULP MILLS	0	JUNE 20,1978
10.	<DP/DT>= 4.1	<DW/DT>= 7.2	<D$/DT>= 5.0	2077 ANIMAL AND MARINE FATS AND OILS	0	JUNE 20,1978
11.	<DP/DT>= 4.6	<DW/DT>= 7.7	<D$/DT>= 5.0	2046 WET CORN MILLING	0	JUNE 20,1978
12.	<DP/DT>= 3.8	<DW/DT>= 8.5	<D$/DT>= 4.6	2044 RICE MILLING	0	JUNE 20,1978
13.	<DP/DT>= 7.2	<DW/DT>= 7.9	<D$/DT>= 4.7	2999 PETROLEUM AND COAL PRODUCTS, NEC	0	JUNE 20,1978

1.	<DP/DT>= 3.2	<DW/DT>= 6.7	<D$/DT>= 2.6	3700 TRANSPORTATION EQUIPMENT LESS 3792	0	JUNE 20,1978
2.	<DP/DT>= 3.3	<DW/DT>= 6.2	<D$/DT>= 3.5	2000 FOOD AND KINDRED PRODUCTS	0	JUNE 20,1978
3.	<DP/DT>= 4.4	<DW/DT>= 6.2	<D$/DT>= 2.0	2800 CHEMICALS AND ALLIED PRODUCTS	0	JUNE 20,1978
4.	<DP/DT>= 3.5	<DW/DT>= 6.6	<D$/DT>= 2.9	2600 PAPER AND ALLIED PRODUCTS	0	JUNE 20,1978
5.	<DP/DT>= 4.0	<DW/DT>= 5.7	<D$/DT>= 2.3	3800 INSTRUMENTS AND RELATED PRODUCTS	0	JUNE 20,1978
6.	<DP/DT>= 3.9	<DW/DT>= 7.1	<D$/DT>= 2.7	3721 AIRCRAFT	0	JUNE 20,1978
7.	<DP/DT>= 4.8	<DW/DT>= 6.0	<D$/DT>= 3.2	2020 DAIRY PRODUCTS	0	JUNE 20,1978
8.	<DP/DT>= 5.5	<DW/DT>= 6.2	<D$/DT>= 2.6	2080 BEVERAGES	0	JUNE 20,1978
9.	<DP/DT>= 3.5	<DW/DT>= 6.5	<D$/DT>= 2.5	2650 PAPERBOARD CONTAINERS AND BOXES	0	JUNE 20,1978
10.	<DP/DT>= 3.7	<DW/DT>= 5.9	<D$/DT>= 3.5	2011 MEAT PACKING PLANTS	0	JUNE 20,1978
11.	<DP/DT>= 3.9	<DW/DT>= 6.8	<D$/DT>= 1.8	2390 MISC. FABRICATED TEXTILE PRODUCTS	0	JUNE 20,1978
12.	<DP/DT>= 5.3	<DW/DT>= 5.8	<D$/DT>= 2.8	2026 FLUID MILK	0	JUNE 20,1978
13.	<DP/DT>= 3.5	<DW/DT>= 7.0	<D$/DT>= 3.3	2621 PAPER MILLS, EXC BUILDING PAPER	0	JUNE 20,1978
14.	<DP/DT>= 3.5	<DW/DT>= 7.0	<D$/DT>= 3.3	2620 PAPER MILS, EXCEPT BUILDING PAPER	0	JUNE 20,1978
15.	<DP/DT>= 5.4	<DW/DT>= 6.2	<D$/DT>= 2.2	2860 INDUSTRIAL ORGANIC CHEMICALS	0	JUNE 20,1978

1.	<DP/DT>= 3.7	<DW/DT>= 5.6	<D$/DT>= 1.5	3600 ELECTRIC AND ELECTRONIC EQUIPMENT	0	JUNE 20,1978
2.	<DP/DT>= 3.8	<DW/DT>= 6.0	<D$/DT>= 1.8	2200 TEXTILE MILL PRODUCTS	0	JUNE 20,1978
3.	<DP/DT>= 6.8	<DW/DT>= 6.6	<D$/DT>=-0.3	3670 ELECTRONIC COMPONENTS AND ACCESSORIES	0	JUNE 20,1978
4.	<DP/DT>= 7.6	<DW/DT>= 6.8	<D$/DT>=-1.0	3679 SEMICONDUCTRS & ELEC COMPONENTS (3674,75,76,77,78,79)	0	JUNE 20,1978
5.	<DP/DT>= 6.3	<DW/DT>= 6.2	<D$/DT>= 0.4	2250 KNITTING MILLS	0	JUNE 20,1978
6.	<DP/DT>= 5.4	<DW/DT>= 6.0	<D$/DT>= 0.6	3570 OFFICE AND COMPUTING MACHINES	0	JUNE 20,1978
7.	<DP/DT>= 4.0	<DW/DT>= 4.1	<D$/DT>= 0.8	3630 HOUSEHOLD APPLIANCES	0	JUNE 20,1978
8.	<DP/DT>= 5.1	<DW/DT>= 5.5	<D$/DT>= 0.1	3573 ELECTRONIC COMPTG EQUIP & CALC MACHINES (3573,74)	0	JUNE 20,1978
9.	<DP/DT>= 3.4	<DW/DT>= 6.2	<D$/DT>= 1.6	2280 YARN AND THREAD MILLS	0	JUNE 20,1978
10.	<DP/DT>= 5.0	<DW/DT>= 6.3	<D$/DT>= 0.4	2830 DRUGS	0	JUNE 20,1978
11.	<DP/DT>= 8.0	<DW/DT>= 6.0	<D$/DT>=-1.3	3650 RADIO AND TV RECEIVING EQUIPMENT	0	JUNE 20,1978
12.	<DP/DT>= 5.0	<DW/DT>= 6.4	<D$/DT>= 0.5	2834 PHARMACEUTICAL PREPARATIONS	0	JUNE 20,1978
13.	<DP/DT>= 5.6	<DW/DT>= 6.1	<D$/DT>= 1.8	2869 INDUSTRIAL ORGANIC CHEMICALS, NEC	0	JUNE 20,1978
14.	<DP/DT>= 7.3	<DW/DT>= 6.0	<D$/DT>=-0.5	2251 HOSIERY (2251,52)	0	JUNE 20,1978
15.	<DP/DT>= 9.1	<DW/DT>= 6.3	<D$/DT>=-1.7	3651 RADIO AND TV RECEIVING SETS	0	JUNE 20,1978

Source: Bureau of Labor Statistics.

REFERENCES

1. Zvi Griliches, "Returns to Research and Development Expenditures in the Private Sector," (Conference on Research in Income and Wealth, 1975); and N. Terleckyj, "Effects of R&D on the Productivity Growth of Industries," (National Planning Association, 1974).

2. Except for semiconductors, the following examples were taken from Burton H. Klein, Dynamic Economics (Cambridge: Harvard University Press, 1977), Chapter V. The semiconductor example is based on research now in progress.

3. Ibid, p. 118.

4. Harold Hotelling, "Stability in Competition, "The Economic Journal (March 1929):41.

5. Roger W. Klein, "Decisions with Estimation Uncertainty," Econometrica 46 (November 1978):1363-1387.

6. Dynamic Economics, pp. 48-50.

7. Harvey Leibenstein, Beyond Economic Man (Cambridge: Harvard University Press, 1976), Chapter 1.

8. Richard M. Cyert and James G. March, A Behavioral Theory of the Firm (Englewood Cliffs: Prentice-Hall, 1963).

9. Paul MacAvoy, The Economic Effects of Regulation: The Trunkline Railroad Cartels and the ICC Before 1900 (Cambridge: MIT Press, 1965).

10. F. M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally & Co., 1971), pp. 376-378.

11. For further discussion see Dynamic Economics, pp. 17-18.

12. For an excellent discussion of the post-World War II challenges to AT&T see Bruce Owen and Ronald Braeutigam, The Regulation Game (Cambridge: Ballinger, 1978).

13. Richard Schmalensee, "Entry Deterrence in the Ready-to-Eat Breakfast Cereal Industry," Bell Journal of Economics (Autumn 1968):437-457.

14. While not all spatial models exhibit equilibria, in the real world the absence of feedback makes an equilibrium stable.

15. Edwin Mansfield, "Innovation and Technological Change in the Railroad Industry," Transportation Economics, publication of

the National Bureau of Economic Research (Princeton: Princeton University Press, 1965).

16. A rough estimate based on fragmentary information.

17. Dynamic Economics, pp. 60-61.

18. William Abernathy, The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry (Baltimore: Johns Hopkins University Press, 1978), pp. 36-37.

19. Probable Levels of R&D Expenditures in 1979: Forecast and Analysis (Columbus: Battelle Memorial Institute, December 1978), pp. 5-6.

20. An estimate based on (1) John W. Kendrich, Postwar Productivity in the United States 1948-1969 (Washington: National Bureau of Economic Research, 1973), pp. 94-95, and (2) information supplied by the Department of Commerce on the implicit deflation.

21. Economic Report of the President (Washington: U. S. Government Printing Office, January 1978), Table B-1, p. 293.

22. Carl Kaysen and Donald Turner, Antitrust Policy: An Economic and Legal Analysis (Cambridge: Harvard University Press, 1959).

23. Bruce Cain, Electoral Volatility in Britain, unpublished manuscript.

24. Morris P. Fiorina, Congress: Keystone of the Washington Establishment (New Haven: Yale University Press, 1957).